Agilent Technologies
Optimizing Your TDMA Network Today and Tomorrow
Interference Identification for IS-136 TDMA Wireless Networks
Application Note 1342

In this application note you will find methods that can be used to easily identify interfering base stations by relying on a measurement receiver to decode the DVCC of IS-136 TDMA channels. To properly describe these methods, background material is provided in Sections 2, 3 and 4.

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Section 1. Introduction to drive-testing

The growth and expansion of cellular and PCS networks continues at a rapid pace throughout the world. To retain existing customers and attract new customers, wireless service providers must maintain the highest quality of service throughout their networks. Drive-testing remains an essential part of the network life cycle, as an effective means for continually optimizing network performance to maintain customer satisfaction and reduce subscriber churn.

This application note provides an overview of how drive-test tools can help optimize your TDMA-based cellular and PCS networks. These tools allow you to turn-up networks faster, reduce optimization time, and improve network quality of service.

Drive-test solutions are used for collecting measurements over a TDMA air interface. The optimum solution combines network-independent RF measurements using a digital receiver with traditional phone-based measurements. A typical collection system includes a digital RF receiver, phone, PC, GPS receiver and antennas. Refer to Figure 1.

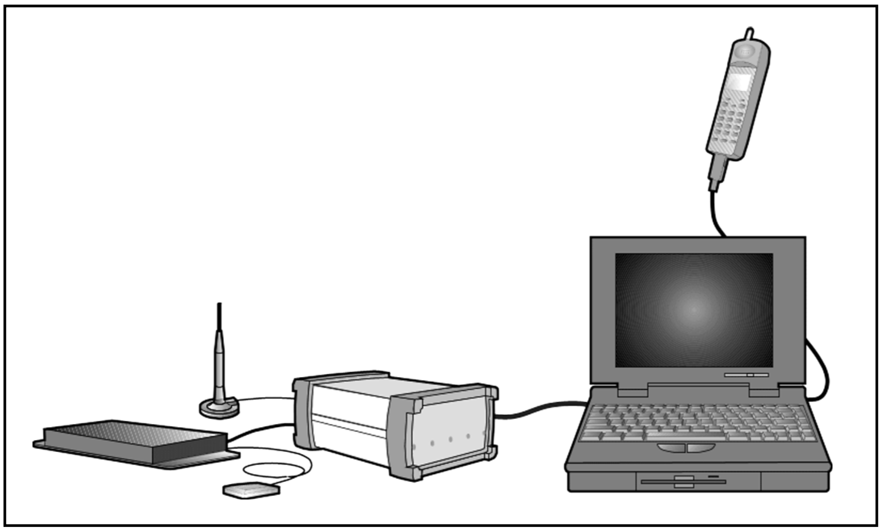

Figure 1. Optimum drive-test solution consists of an integrated digital receiver and phone. A GPS receiver is required for location information.

Optimization process

Optimization is an important step in the life cycle of a wireless network. An overview of the optimization process is illustrated in Figure 2. Drive-testing is the first step in the process, with the goal of collecting measurement data as it relates to the user's location. Once the data has been collected over the desired RF coverage area, the data is output to a post-processing software tool or mapping software such as MapInfo. Engineers can use these tools to identify the causes of potential RF coverage or interference problems and analyze how these problems can be solved. Once the problems, causes, and solutions are identified, steps are performed to solve the problem.

Figure 2 illustrates that optimization is an ongoing process. The goal is to improve quality of service, retain existing subscribers, and attract new ones while continually expanding the network.

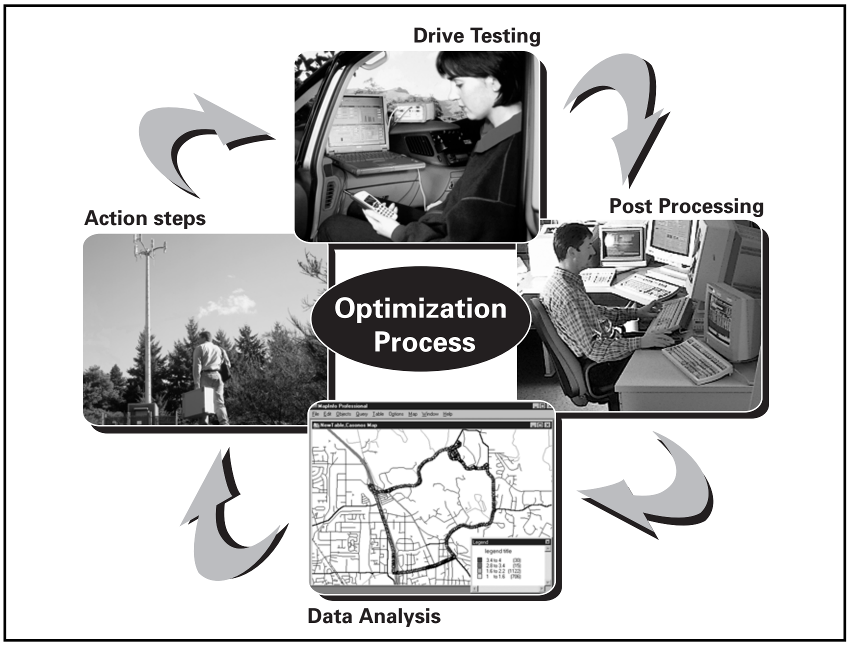

Figure 2. The optimization process begins with drive-testing, moves to post-processing, then requires data analysis, and finally action needs to be taken correct the problems. Drive-testing is performed again to verify that the actions were effective.

Section 2. Introduction to IS-136 TDMA networks

In recent years the number of wireless networks based on the IS-136 standard has grown considerably throughout both North America and Latin America. Many of these networks evolved from the Advanced Mobile Phone System (AMPS) standard. In anticipation of addressing capacity concerns, the IS-54 standard was written, enabling TDMA systems in the cellular frequency range (850 MHz). IS-54 based networks were implemented, offering capacity relief to crowded AMPS networks. As PCS frequencies became available, the IS-136 standard emerged, providing the same TDMA operation as IS-54 in both the cellular (850 MHz) and PCS (1900 MHz) bands. It also and provided the mechanism for additional services. Today, mobile handsets are readily available that can operate in TDMA and AMPS modes, and in both the cellular and PCS bands.

For channel assignments, the original AMPS wireless networks relied on Frequency Domain Multiple Access (FDMA). To transmit and receive in FDMA systems, each user was assigned a dedicated frequency. In the case of AMPS, each channel is 30 kHz wide and uses frequency modulation (FM) to transport conversations. Since the amount of spectrum owned by wireless service providers is limited to a fixed number of 30 kHz channels, each channel must be reused many times throughout a network in order to provide enough channel capacity to satisfy customer demand. Two base stations assigned to use the same channel must be located far enough apart so that the channel users do not interfere with each other. To provide satisfactory voice quality in a wireless network, it is important to detect and fix situations in which base stations are interfering with each other.

Section 2. Introduction to IS-136 TDMA networks (continued)

Wireless networks based on the IS-136 standard operate using two methods of access – FDMA and Time Domain Multiple Access (TDMA). The same 30 kHz channel bandwidth used in AMPS systems is used here. Also as with AMPS networks, each channel must be used by multiple base stations, so networks must be engineered to minimize interference between base stations. In addition, three users share each 30 kHz channel. This is accomplished by dividing the channel into time slots so each user of the channel has full use of the channel only one-third of the time. Thus the TDMA network capacity is tripled as compared to an AMPS network.

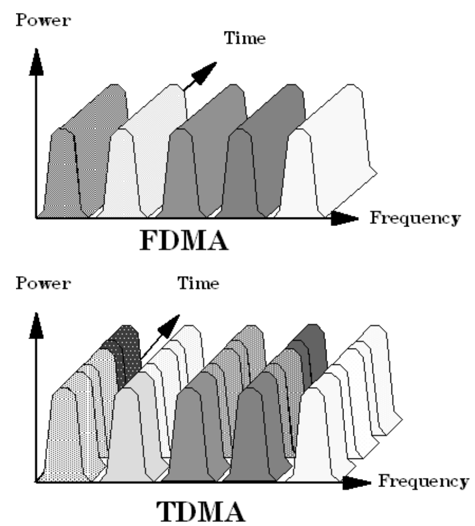

Figure 3. In AMPS systems, each conversation is assigned a 30 kHz channel. In TDMA systems three conversations are assigned to each 30 kHz channel. Each conversation uses the channel1/3 of the time.

Interference between base stations can exist since each channel is used in more than one base station. If two base stations are using the same channel simultaneously it can cause co-channel interference or if they are using an adjacent channel simultaneously it can cause adjacent channel interference. To maximize voice quality, both types of interference must be identified and eliminated.

It is not difficult to identify adjacent channel and co-channel interference when optimizing IS-136 TDMA wireless networks. This is typically done using a phone-based drive-test system, which can identify areas of high bit error. However, identifying the base station transmitting the interfering signal can be a challenge. Using a drive-test tool that has both phone- and receiver-based measurements allows the user to not only identify that interference exist, but also which base station is the source of the interference.

Section 3. Channel planning basics

TDMA wireless service providers need to assign channels to each base station. The channel assignments must be made in a way that minimizes interference. A channel table is used to assign channels for each of the service provider's geographical markets, based on the market needs.

Channel tables are commonly used to group channels into *channel sets*. Channel sets are based on a *channel reuse number* (the number of cells in which all channels will be used once, before they are reused in additional cells). The *channel reuse number* determines the number of columns in the channel table. Typically the number of columns is 3 times the channel reuse number. For example, for a network using 7-cell reuse (channel reuse number = 7) there are 21 columns in the channel table (7 cells x 3 sectors per cell = 21 channel groups). A network with 6-cell reuse would have 18 columns. A network using 12-cell reuse would have 36 columns. The smaller the channel reuse number, the larger the number of channels per channel set. This is true since each of the channels owned by an operator must occupy one spot in the channel table. If the number of columns in the table is decreased then the number of rows will increase. Conversely, if the number of columns increases then the number of rows decreases. Using a smaller channel reuse number requires a shorter distance between sectors that reuse the same channels, since the number of channel sets (columns in the table) is decreased. Tables 1 and 2 contain typical channel tables for both the cellular and PCS bands.

Table 1. Typical A-band cellular channel table with 7-cell reuse

A1	B1	C1	D1	E1	F1	G1	A2	B2	C2	D2	E2	F2	G2	A3	B3	C3	D3	E3	F3	G3
333	332	331	330	329	328	327	326	325	324	323	322	321	320	319	318	317	316	315	314	313
312	311	310	309	308	307	306	305	304	303	302	301	300	299	298	297	296	295	294	293	292
291	290	289	288	287	286	285	284	283	282	281	280	279	278	277	276	275	274	273	272	271
270	269	268	267	266	265	264	263	262	261	260	259	258	257	256	255	254	253	252	251	250
249	248	247	246	245	244	243	242	241	240	239	238	237	236	235	234	233	232	231	230	229
228	227	226	225	224	223	222	221	220	219	218	217	216	215	214	213	212	211	210	209	208
207	206	205	204	203	202	201	200	199	198	197	196	195	194	193	192	191	190	189	188	187
186	185	184	183	182	181	180	179	178	177	176	175	174	173	172	171	170	169	168	167	166
165	164	163	162	161	160	159	158	157	156	155	154	153	152	151	150	149	148	147	146	145
144	143	142	141	140	139	138	137	136	135	134	133	132	131	130	129	128	127	126	125	124
123	122	121	120	119	118	117	116	115	114	113	112	111	110	109	108	107	106	105	104	103
102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85	84	83	82
81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61
60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40
39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19
18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	-	-	-
716	715	714	713	712	711	710	709	708	707	706	705	704	703	702	701	700	699	698	697	696
695	694	693	692	691	690	689	688	687	686	685	684	683	682	681	680	679	678	677	676	675
674	673	672	671	670	669	668	667	-	-	-	-	-	-	-	-	-	-	-	-	-
1023	1022	1021	1020	1019	1018	1017	1016	1015	1014	1013	1012	1011	1010	1009	1008	1007	1006	1005	1004	1003
1002	1001	1000	999	998	997	996	995	994	993	992	991	-	-	-	-	-	-	-	-	-

Table 2. Typical A-band PCS channel table with 12-cell reuse

A1	B1	C1	D1	E1	F1	G1	H1	I1	J1	K1	L1	A2	B2	C2	D2	E2	F2	G2	H2	I2	J2	K2	L2	A3	B3	C3	D3	E3	F3	G3	H3	I3	J3	K3	L3
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108
109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144
145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216
217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252
253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288
289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324
325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360
361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396
397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432
433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468
469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	-	-	-	-	-

Each column of a channel table is a channel set. Channel sets can be named in a variety of ways. Two typical ways are to number the channel sets (1,2,3,…21) and to use the following convention (A1,B1,C1,…A2,B2,C2,…A3,B3,C3…). Refer to Tables 3 and 4 for channel set examples.

Table 3. Channel set A1 taken from A-band cellular table, 7-cell reuse

A1
333
312
291
270
249
228
207
186
165
144
123
102
81
60
39
18
716
695
674
1023
1002

Table 4. Channel set B3 taken from A-band PCS table, 12-cell reuse

B3
26
62
98
134
170
206
242
278
314
350
386
422
458
494

Each row in a channel table can be set aside for a particular use. For example, a row is dedicated to analog control channels in mixed AMPS/TDMA systems. In addition, rows may be set aside for AMPS channels, Digital Traffic Channels (DTCs) and Digital Control Channels (DCCHs). Please refer to Table 5 for an example of assigning dedicated uses for each row in a channel table.

Table 5. A-band cellular channel table showing a designated use for each row

Designated use	A1	B1	C1	D1	E1	G3
Analog control channel	333	332	331	330	329	313
Digital traffic channel	312	311	310	309	308	292
Digital traffic channel	291	290	289	288	287	271
Digital traffic channel	270	269	268	267	266	250
Digital traffic channel	249	248	247	246	245	229
Digital traffic channel	228	227	226	225	224	208
Digital traffic channel	207	206	205	204	203	187
Digital traffic channel	186	185	184	183	182	166
Digital traffic channel	165	164	163	162	161	145
Digital traffic channel	144	143	142	141	140	124
Digital traffic channel	123	122	121	120	119	103
Digital traffic channel	102	101	100	99	98	82
Digital traffic channel	81	80	79	78	77	61
Digital traffic channel	60	59	58	57	56	40
Digital traffic channel	39	38	37	36	35	19
Digital traffic channel	18	17	16	15	14	–
Digital traffic channel	716	715	714	713	712	696
Digital traffic channel	695	694	693	692	691	675
Digital control channel	674	673	672	671	670	–
AMPS	1023	1022	1021	1020	1019	1003
AMPS	1002	1001	1000	999	998	–

Section 4. Channel planning techniques

In general, one channel set is assigned to each base station sector when designing a channel plan for a TDMA/AMPS network. A channel set designation is given to each sector (such as A2 or E3). Just because a channel set is assigned to a sector, it doesn't mean that all the channels in that channel set are used at that sector. The number of channels used depends on the sector's voice traffic demand. Only a few channels are used in areas of low mobile phone density, while all the channels in the channel set are used in areas of high mobile phone density. Some sectors with very high usage may require assignment of additional channel sets in order to have enough channels to handle customer demand.

Channel plans can be designed so channel sets are assigned once in each reuse cluster (once every 7 cells in a system using a reuse number of 7). Figure 4 shows several clusters of cells. Each cell cluster is shaded the same way. Cells that use the same channel are labeled with the same number. However, cells aren't always built on a grid with an equal distance of separation. Terrain and traffic loading pose challenges to a standard reuse plan. Channel sets are not always assigned in reuse clusters, but are instead assigned where they will cause the least amount of interference.

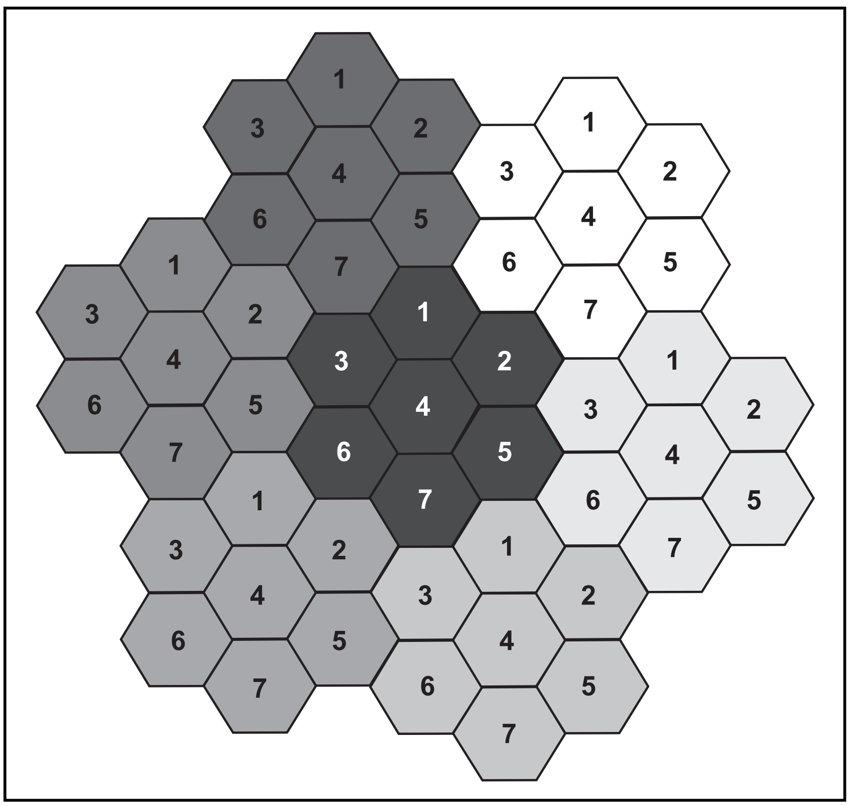

Figure 4. Cell clustering.

Section 4. Channel planning techniques (continued)

Most TDMA infrastructure allows the channels in a base station to be utilized in order according to an *assignment list*. This means that the first channel in the assignment list is the first channel to be assigned a call. If another call is set up it will be assigned to the second channel in the assignment list and so on. Using this method, the first channel in the assignment list will have the highest amount of usage and the last channel in the assignment list will have the least amount of usage. The last channels in the assignment list will only be used during the periods of time when the sector is busiest.

When assigning multiple sectors of a network to use the same channel set, *alternating channel assignment* can be used to minimize the probability of co-channel interference. Alternating channel assignment takes two of the closest sectors and assigns them the same channel set, but their channels are assigned in alternate directions. One sector will use the lowest channel number in the channel set then gradually increase to higher channel numbers, until there are enough channels assigned to meet the traffic demand. The other sector (assigned with the same channel set) uses the highest channel number in the channel set, then gradually decreases to lower channel numbers until there are enough channels assigned to meet traffic demand. If the two sectors don't require all the channels in the channel set be used, then some channels used at one sector will not be used at the other sector. There will be no co-channel interference between the sectors for these channels – consisting of the highest and lowest channel numbers in the channel set. This method is not as beneficial if either of the sectors require all channels in the channel set.

Section 4. Channel planning techniques (continued)

The previous example of two of the closest sectors being assigned to the same channel set, helps illustrate the power of using *alternating channel assignment* and *assignment lists* in conjunction. One sector is given an assignment list, which starts with the lowest channel number then ends with the highest used channel number in the channel set. The other sector's assignment list is just the opposite, starting with the highest number in the set and ending with the lowest assigned channel. Using this method minimizes the probability of co-channel interference between the two sectors. Table 6 illustrates the assignment list and alternating channel assignment techniques.

Table 6. Channel plan for channel set A1

Set A1	**Sectors assigned to use channel set A1**							
Channel number	2γ	6β	18α	23β	34α	40α	44α	53β
333	1	21		1		1	1	1
312	2	20		2		2	2	2
291	3	19		3		3	3	3
270	4	18		4		4	4	4
249	5	17		5		5	5	5
228	6	16		6		6	6	6
207	7	15		7		7	7	7
186	8	14		8			8	8
165	9	13		9			9	9
144	10	12		10			10	10
123	11	11		11	11		11	11
102		10		12	10		12	12
81		9		13	9		13	13
60		8		14	8		14	14
39		7	7	15	7		15	15
18		6	6	16	6			16
716		5	5	17	5			17
695		4	4		4			18
674		3	3		3			19
1023		2	2		2			20
1002		1	1		1			21

The first column of Table 6 contains the channel numbers in the A1 channel set. Each additional column contains data for a sector assigned to use channel set A1. The numbers listed under the sector name in the table represent the position in the *assignment list* for the respective channel. Each sector of a base station is designated as the alpha (α), beta (β) or gamma (γ) sector. Notice that all the sectors are assigned to the channel set but they don't necessarily use all the channels in the channel set. Sectors 6β and 53β must handle a large amount of traffic and therefore utilize all the channels in the channel set. Sector 2γ only needs to use channels 333-123. If demand increased at sector 2γ then channels 102-1002 could be used. Notice that sector 40α has low demand, only requiring the use of 7 channels. Sectors 2γ and 34α use the *alternating channel assignment* technique.

Section 4. Channel planning techniques (continued)

They both require 11 channels but the channels are assigned at opposite ends of the channel set, so that only the 11th channel (channel 123) has the possibility of co-channel interference. Sectors 18α and 40α also use the *alternating channel assignment* technique; in this case there is no overlap of channels and therefore no possibility of co-channel interference between the two sectors. The *assignment list* technique is used with sectors 6β and 53β. They both require 21 channels and so the potential for co-channel interference between the two sites is present on all channels. The amount of interference in minimized by using the lower channels in the table first at 6β and by using the upper channels in the table first for 53β.

Since 11 is the last position in the assignment list, the probability that 2γ and 34α will be using channel 123 at the same time is minimized since channels with a lower position in the assignment list will be used first.

Figure 5 shows where each of the sectors in Table 6 might be located on a site map. It also shows which sectors are using the A1 channel set. This diagram is useful in determining which sectors are likely to interfere with each other based upon their proximity. Information about the orientation of each sector is also conveyed.

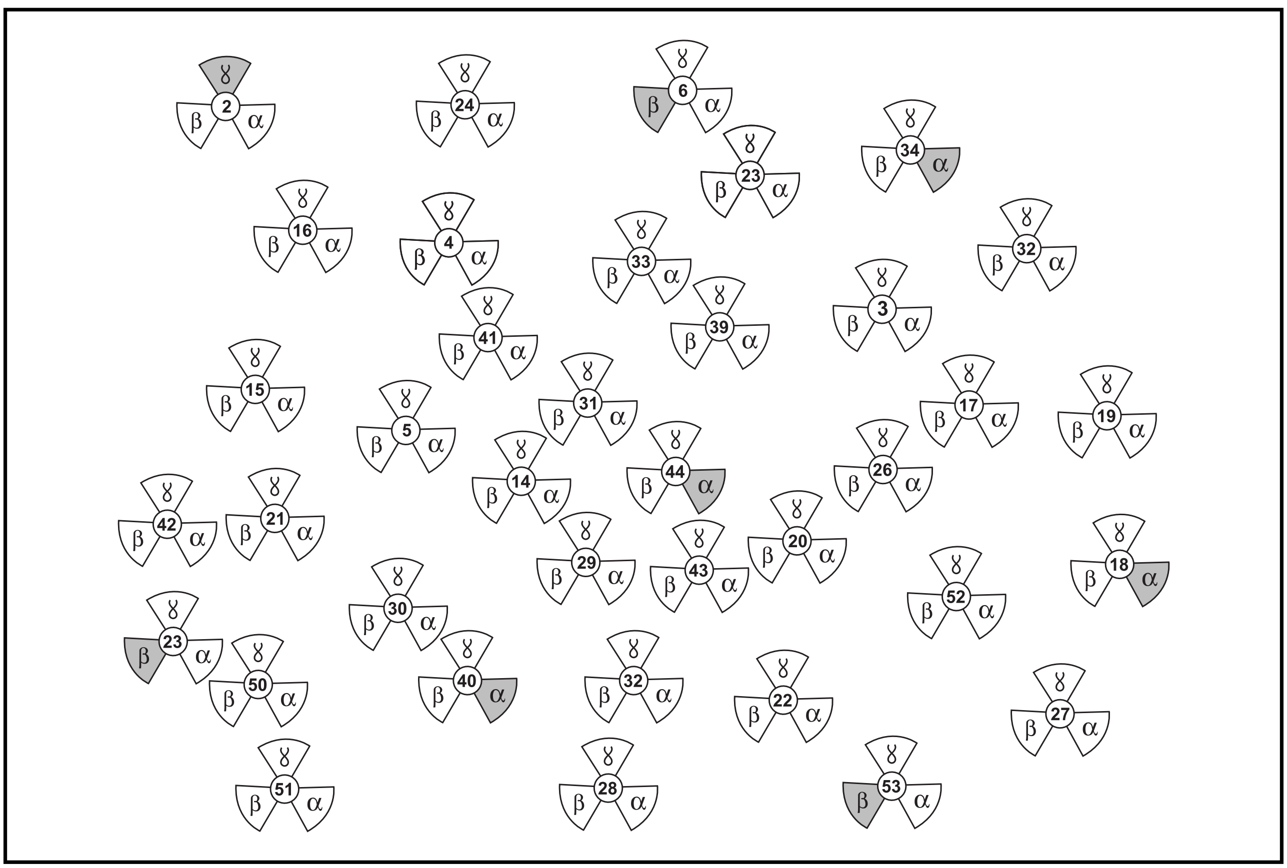

Figure 5. Base station location with channel set reuse emphasized. All shaded sectors use the A1 channel set, according to Table 6.

Section 5. Interference guidelines

This section gives quantitative measures for describing interference. Two types of self-imposed interference are present in TDMA systems – adjacent channel and co-channel interference. When channel planning, it is important not to use adjacent channel groups too close together because the two channels can interfere with each other. There is no guard band between 30 kHz TDMA channels, so the network designer must implement a guard band by properly assigning channels. How close together can sectors be which use the same channel set? When frequency planning, the carrier channel must always be stronger than any adjacent channel. If one of the two adjacent channels is ever stronger than the serving channel, voice quality will begin to degrade (bit errors will be induced). To quantify this condition the carrier to adjacent ratio can be used (C/A). The C/A is found by subtracting the dBm value of the adjacent channel from the dBm value of the serving channel. If the C/A is less than or equal to zero, voice quality will begin to degrade.

Interference on the same channel as the serving channel must also be considered. In this case the signal coming from any base station other than the serving base station (the one communicating with the phone) must be 17 dB lower than the serving signal. If it is higher, voice quality will begin to degrade. Planning adequate isolation between sectors that use the same channel set will ensure interfering signals are 17 dB lower than the serving signal. The carrier to interference ratio is used to quantify co-channel interference. The C/I is found by subtracting the dBm value of the interfering signal from the dBm value of the serving signal. If the C/I is less than 17 dB then voice quality will begin to degrade.

Section 6. What is the DVCC?

The Digital Verification Color Code (DVCC) is a signal sent from the base station to the phone, then from the phone back to the base station. When the phone transmits the DVCC on the uplink it must send the DVCC that it received from the base station on the downlink. The phone cannot use prior knowledge of the DVCC. It is not allowed to send the correct DVCC on the uplink if it received the wrong DVCC on the downlink. If the correct DVCC is not received by the base station on the uplink then the phone call may be handed off or dropped after a period of time specified by the network operator. The DVCC is heavily error coded before it is transmitted so that the DVCC can be correctly decoded despite some amount of bit error. In cases when the heavily protected DVCC code is not making it through correctly on both the downlink and uplink, then some impairment must be present which is causing bit errors.

Typically the same DVCC is assigned to all sectors of a base station. The DVCC is transmitted on both Digital Control Channels (DCCH) and on Digital Traffic Channels (DTC). Since there are 255 unique DVCCs, there is usually great distance between base stations that use the same DVCC. Each of the 255 DVCCs are assigned to a base station before having to reuse the DVCC for an additional base station. Since the same DVCC is typically used for all sectors of a base station, the DVCC reuse will occur only in systems having more than 255 base stations. Once a DVCC must be used in more than one base station, the base stations can be isolated by a large distance, thus having little chance to interfere with each other.

Section 7. Method for adjacent channel interference identification

When there is adjacent channel interference, bit errors occur and voice quality degrades. Many receiver-based drive-test tools are available to help identify that the adjacent channel C/A guideline (C/A >0) has been violated. In Figure 6 the horizontal axis is used for channel number and the vertical axis is used for signal strength (in dBm). The figure illustrates an adjacent channel interference problem since channel 212 is stronger than the serving signal, channel 211. The channel number of the serving channel can be determined using a phone-based drive-test tool.

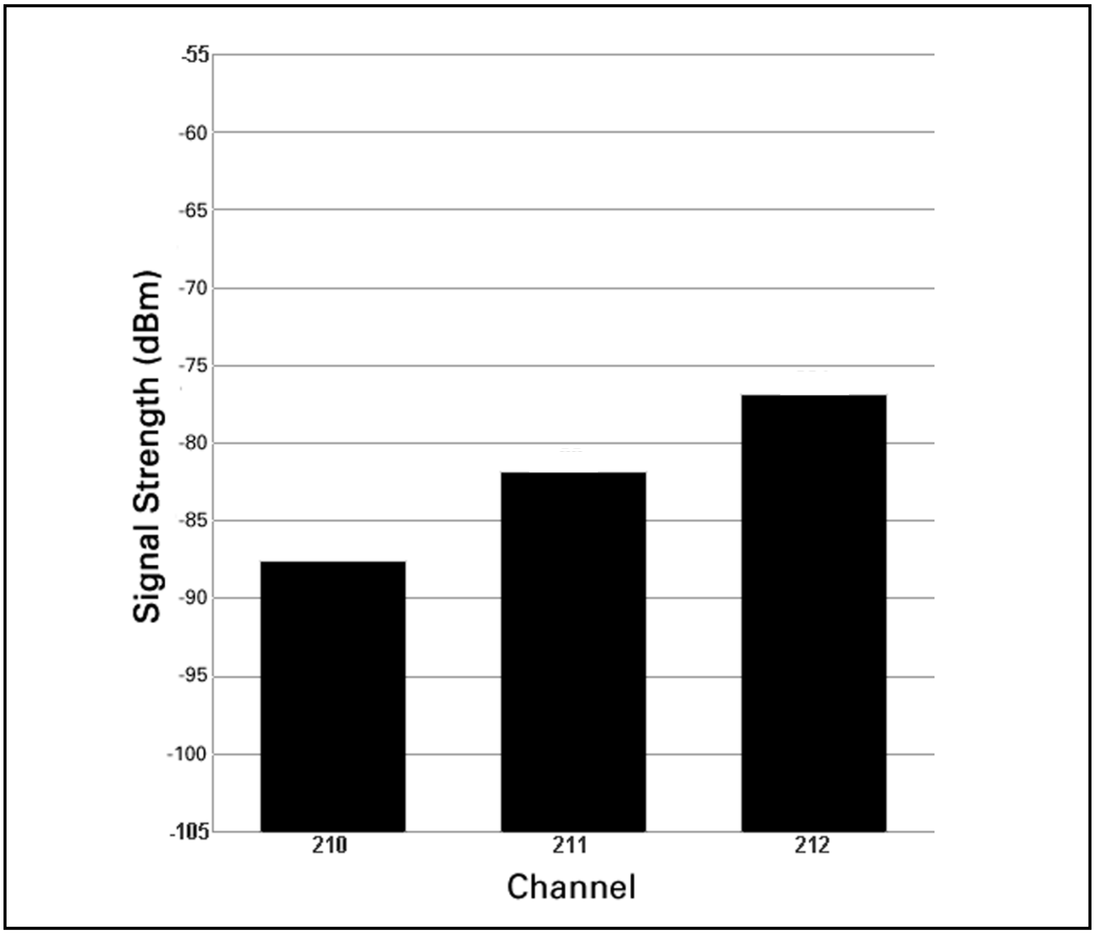

Figure 6. Adjacent channel interference example.

Bit errors will occur on channel 211 due to the strong signal present on channel 212. Knowing that the interfering signal is on channel 212 is useful. A channel plan can now be used to determine the source of the strong signal on channel 212. First, examine the channel table for channel set D3, of which channel 211 is a member. For this example assume that the serving sector is 5β. Notice that the techniques of alternating channel assignment and assignment list and channel assignment are used in Table 7.

Table 7. Channel plan for channel set D3

Set D3	**Sectors assigned to use channel set D3**							
Channel number	3γ	5β	30α	39β	45α	70α	89α	103β
316	1	16		1		1	1	1
295	2	15		2		2	2	2
274	3	14		3		3	3	3
253	4	13		4		4	4	4
232	5	12		5		5	5	5
211	6	11		6		6	6	6
190	7	10		7		7	7	7
169	8	9		8	9		8	8
148	9	8		9	8		9	9
127	10	7	7	10	7		10	10
106	11	6	6	11	6		11	11
85		5	5	12	5		12	12
64		4	4	13	4		13	13
43		3	3	14	3		14	14
22		2	2	15	2		15	15
1		1	1	16	1			16

A strong signal on channel 212 is causing interference on channel 211.
The channel plan for the E3 channel set can be used to determine which sectors are assigned to use channel 212. In examining Table 8 for the E3 channel set, notice that sectors 81α and 158β are assigned to the E3 channel set, but do not use channel 212.

Table 8. Channel plan for channel set E3

Set E3	**Sectors assigned to use channel set E3**							
Channel number	17α	26β	38β	49γ	81α	109γ	158β	234γ
317	1		1	1		1		1
296	2		2	2		2		2
275	3		3	3		3		3
254	4	13	4	4		4		4
233	5	12	5	5		5		5
212	6	11	6	6		6		6
191	7	10	7	7	10	7		7
170	8	9	8	8	9	8		8
149	9	8	9	9	8	9		9
128	10	7	10	10	7	10	7	10
107	11	6	11	11	6	11	6	11
86	12	5		12	5	12	5	12
65	13	4		13	4		4	13
44	14	3		14	3		3	14
23	15	2		15	2		2	15
2		1		16	1		1	16

The channel plan in Table 8 shows that the sectors in Table 9 are potential interferers since they all use channel 212. Which of the potential interferers is the actual interferer? The answer to this question depends on many factors. Using knowledge of the base station locations, terrain, antenna heights and orientations, each potential interferer can be evaluated. The results will be as illustrated in Table 9. Some sectors can be ruled out based on network specific knowledge, such as 38β and 49γ in Table 9. Other sectors are highly likely to interfere, as illustrated by sectors 17α and 234γ in Table 9. The remaining sectors are more difficult to classify, such as 26β and 109γ below. Additional steps must now be taken to determine the interferer. Typically additional drive-testing is required to gain additional information needed to determine the source of the interference. In this example additional investigation would need to be conducted for the following sectors: 17α, 26β, 109γ and 234γ.

Table 9. Potential interferers on channel 212

Potential interferers on channel 212	**Interference likely?**
17α	Yes
26β	Maybe
38β	No
49γ	No
109γ	Maybe
234γ	Yes

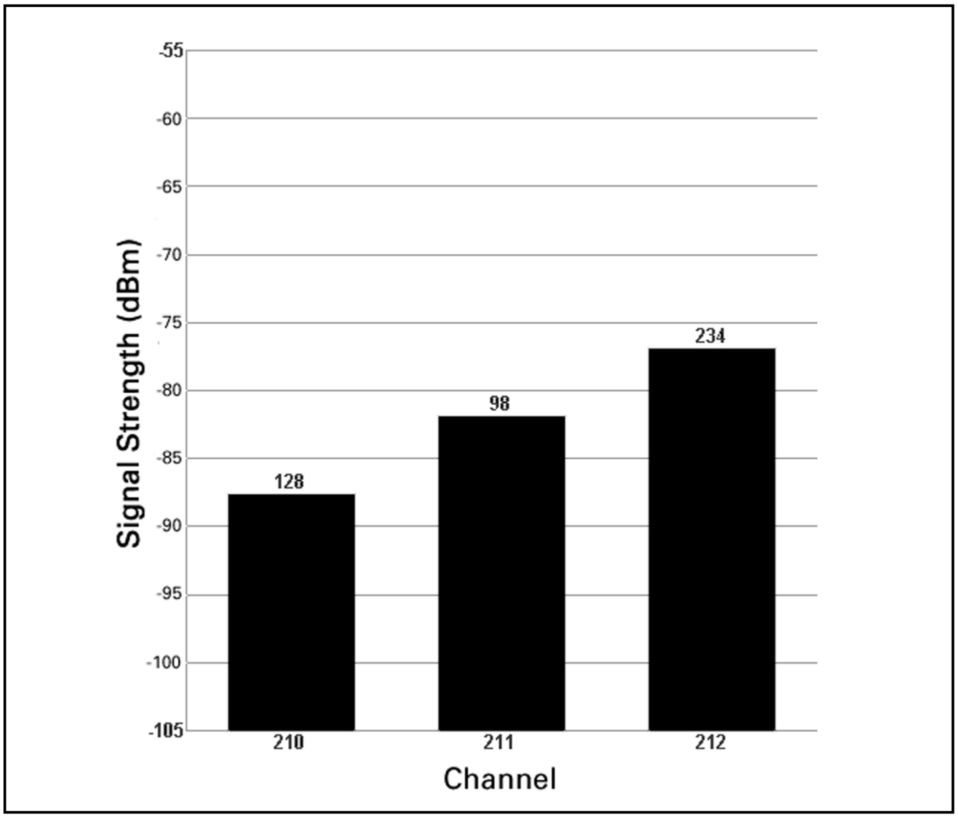

Figure 7. Adjacent channel interference with DVCC decode.

The process of identifying the interfering base station is simplified if a drive-test tool is able to provide the channel number, power level of the interfering signal and the DVCC of the interfering signal. Figure 7 shows a strong signal on channel 212, which is adjacent to the serving channel 211. In addition, the DVCC of the signal on channel 212 is shown on top of the bar. In this case the DVCC is 234.

Knowing the DVCC, a new table can now be constructed to help identify the interferer. All the sectors using channel 212 are listed, along with the DVCC assigned to each of those sectors. From Figure 7, the DVCC of the interferer was identified as 234. Using the following table it is clear to see that 234γ is the signal transmitting the interfering sector since it is the only sector assigned both channel 212 and DVCC 234. No guesswork or additional investigation is required since the interferer has been uniquely identified. Using this method reduces drive-test and investigation time. Now that the offending base station has been identified, steps can be taken to solve the interference problems. These steps may include channel plan changes, antenna height or orientation changes, and others.

Table 10. Potential interferers on channel 212

Potential interferers on channel 212	DVCC	Interferer?
17α	17	No
26β	26	No
38β	38	No
49γ	49	No
109γ	109	No
234γ	234	Yes

Section 8. Methods for co-channel interference identification

To illustrate a process for identifying co-channel interferers refer to Table 11. While drive-testing with a phone-based tool, severe bit error problems are encountered on channel 314 of sector 194α. Using a channel plan for channel set B2 in a system with a reuse number of 12, all of the sectors that are assigned channel 314 can be identified.

Table 11. Channel plan for channel set B2

Set B2	Sectors assigned to use channel set B2							
Channel number	3α	37β	68β	100β	141α	164β	194α	203β
494	1	1		1		1	1	1
458	2	2		2		2	2	2
422	3	3		3		3	3	3
386	4	4		4		4	4	4
350	5	5		5		5	5	5
314	6	6		6		6	6	6
278	7			7		7	7	7
242	8			8	1			8
206	9			9	2			9
170	10		5	10	3			10
134	11		4	11	4			11
98			3	12				12
62			2	13				13
26			1	14				14

Once identified, a list of potential interferers can be built. Refer to Table 12 for the list of interferers. Notice that even though sectors 68β and 141α are assigned to the B2 channel set they are not potential interferers since they are not assigned channel 314. Each potential interferer can be evaluated using knowledge of the base station locations, terrain, antenna heights and orientations. The results of this evaluation are illustrated in Table 12 below. Some sectors can be ruled out, such as 3α. Other sectors are highly likely to interfere, as illustrated by sectors 37β and 100β in Table 12. The remaining sectors are more difficult to classify, such as 164β and 203β in Table 12. Additional steps must now be taken to determine the interferer. Additional drive-testing would typically be required to gain additional information needed to determine the source of the interference. From Table 12 additional investigation would need to be conducted for the following sectors: 37β, 100β, 164β and 203β. No further investigation would be needed if the DVCC of the interferer was known, since the interferer would be uniquely identified. For example, if the DVCC was known to be 37, then 37β would be the interferer.

Table 12. Potential interferers on channel 314

Potential interferers on channel 314	DVCC	Interferer?
3α	3	No
37β	37	Yes
100β	100	Yes
164β	164	Maybe
203β	203	Maybe

Section 8. Methods for co-channel interference identification (continued)

The DVCC of the interferer can be determined using one of three methods: *clear channel*, *wait for idle channel or force idle channel*. All three methods involve monitoring all the channels in the serving channel's channel set. These channels are monitored for their power level and their decoded DVCC value. To determine the interferer in Table 12, the B2 channel set must be monitored using a drive-test tool with a display like Figure 8. In all three methods it may be necessary to monitor the B2 channel set over a period of time by driving through the area of interference. The Figure 8 shows all the channels of the B2 channel set across the horizontal axis. Signal strength (in dBm) is shown on the vertical axis. The decoded DVCC value of each channel is shown above the channel's bar.

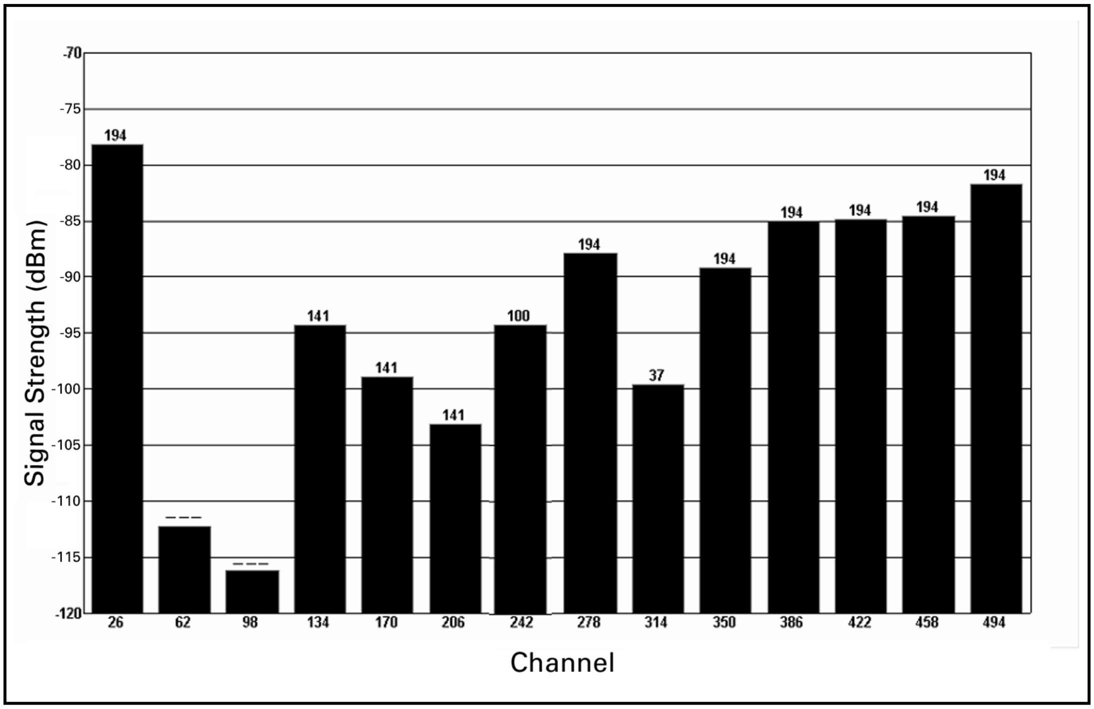

Figure 8. Sample plot of channel set B2 channels.

Clear channel method

The first method, *clear channel*, involves looking for a clear channel, one that is used at the potentially interfering base station, but not at the serving base station. In Table 11, sector 100β fits this description. Sector 100β has radios assigned on channels 242, 206, 170, 134, 98, 62 and 26. All of these channels are clear channels with respect to 194α. At the serving base station, 194α, no radios are assigned to any of these channels so none of them will ever be in use at 194α (this can be determined using the table for channel set B2 shown in Table 11). All of the clear channels can be monitored using a measurement receiver capable of decoding DVCC. If the receiver is able to decode a DVCC of 100 on any of the clear channels, then the power level of signals coming from sector 100β can be compared with the power level of signals coming from 194α, used to determine an inferred carrier to interference ratio (C/I). The C/I will be accurate if all channels in a sector are set to transmit at the same power level. This practice is followed in nearly all cases, except when downlink power control is implemented. In Figure 9, since the receiver is able to decode a DVCC of 100 on channel 242, it is certain that the signal is coming from sector 100β. If the signal from sector 100β on the clear channel (channel 242) is strong enough to interfere with the signal from 194α (the inferred C/I is less than 17 dB), then it can be inferred that 100β is interfering with 194α on channels 494-278 (the channels that are in use at both sites). Thus sector 100β is extremely likely to be the source of the interference on channel 314.

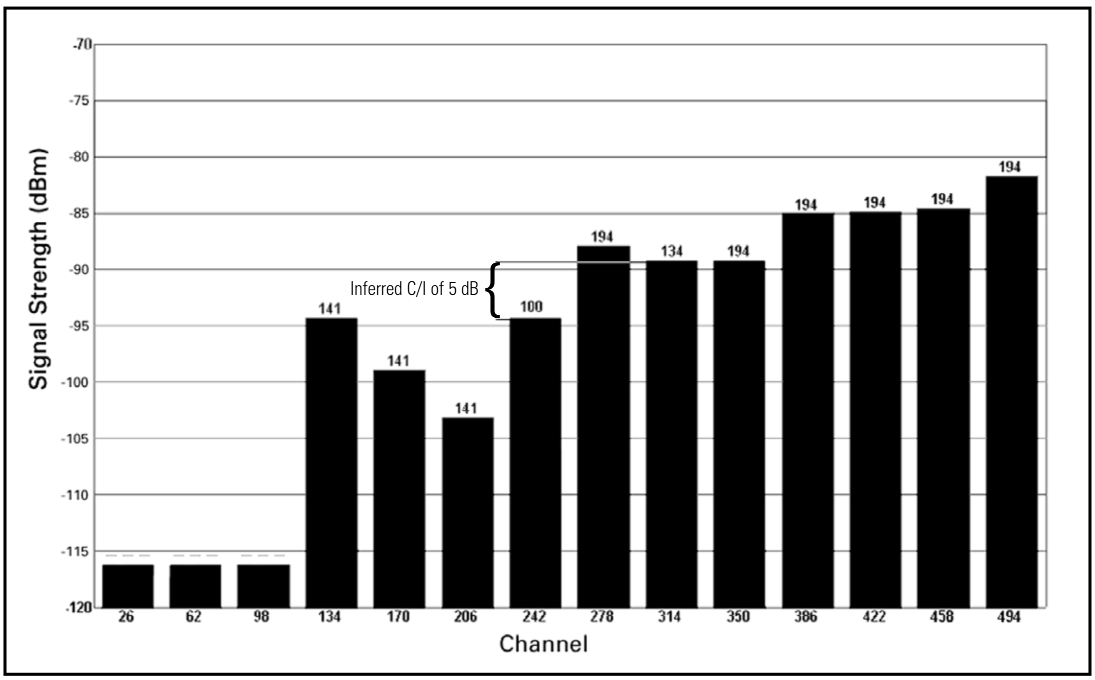

Figure 9. Co-channel interferer identification using clear channel method.

Wait for idle channel method

The next method, *wait for idle channel*, applies to potentially interfering base stations that have channels that completely overlap with the serving base station. In the example shown in Table 11, sector 37β fits this description since there are no channels in use at 37β that are not also in use at 194α. In this case there is no clear channel to monitor, instead all overlapping channels are monitored (channels 494-314). During times when one of the overlapping channels is not in use at the serving base station, 194α, that channel can be monitored by the receiver. If the receiver can decode a DVCC of 37 on the channel while it is not in use at 194α, then the signal level can be compared to other channels that are currently in use at 194α to infer a C/I value. In order for the inferred value to be correct all radios assigned to a sector must be set to the same power level. If the C/I is less than 17 dB then it almost certain that 37β is the interfering sector causing bit error problems on channel 314. This method requires the user to monitor channels over time, waiting for channels at 194α to go idle and hoping that while idle at 194α, the same channel is active at 37β. This method can be used on any of the overlapping channels (494-314).

Figures 10 and 11 illustrate this method. Notice in Figure 9 that channel 314 is currently active at sector 194α. This is apparent since a DVCC of 194 is displayed. In Figure 11, channel 314 is no longer active at sector 194α but a signal is present. The signal has a DVCC of 37 so it must be coming from sector 37β, which is the only sector to use channel 314 and DVCC 37.

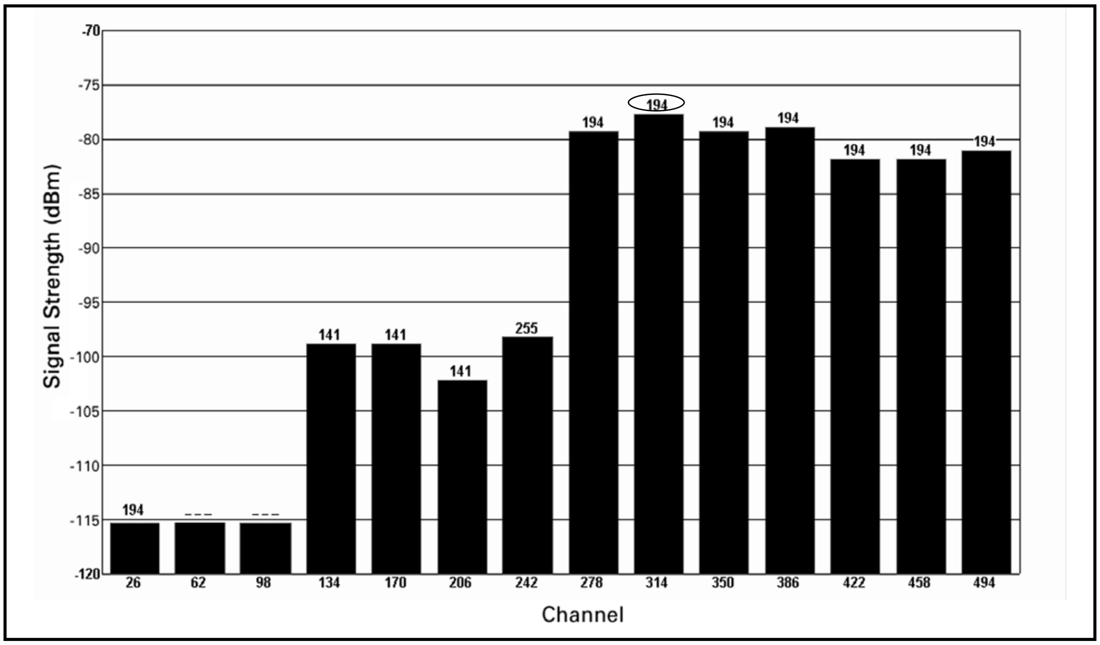

Figure 10. Co-channel interferer identification using wait for idle method, channel 314 is busy at the serving sector, 194α.

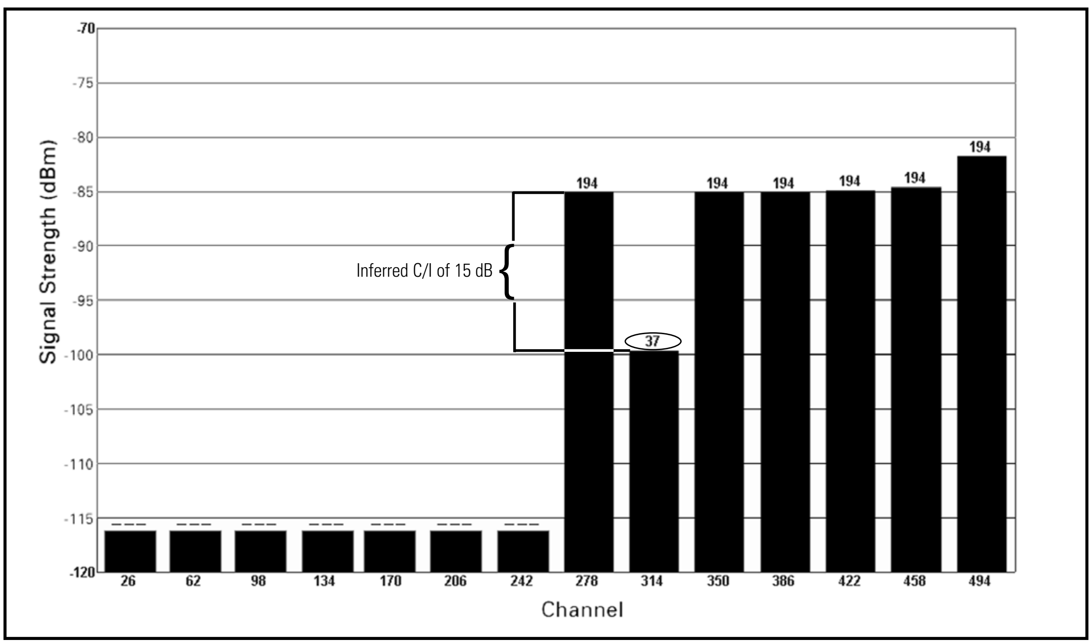

Figure 11. Co-channel interferer identification using wait for idle method, channel 314 is idle at the serving sector 194α but in use at 37β, note that the DVCC of channel 314 changed from 194 to 37.

Force idle channel method

Finally, *force idle channel* is the last method. Force idle channel applies to potentially interfering base stations with channels that completely overlap with the serving base station, as in the wait for idle channel method. The force idle channel method is the same as wait for idle channel method except that it does not require that the user wait for channels to go idle at the serving base station and hope that the same channel will be active at the interfering base station. Instead a channel is temporarily forced to be idle at the serving base station and the same channel is temporarily forced to be active at the potentially interfering base station. Force idle channel is quicker than the wait for idle method, but requires the user to send control commands to the serving base station and to the potentially interfering base stations in order to force the channels idle and active respectively. Force idle channel method can be used if there is high channel usage at the serving base station, making the wait for idle method ineffective.

All three methods discussed can be effective in determining the DVCC of the interfering base station. Using these methods saves time over methods that don't involve the use of decoded DVCC because they provide the user with the ability to definitely determine the base station transmitting the interfering signals. Once the interfering base station has been identified, steps can be taken to solve the interference problems. As with adjacent channel interference, these steps may include channel plan changes, antenna height or orientation changes, and others.

Section 9. Conclusion

Adjacent and co-channel interference problems in IS-136 TDMA wireless networks are not difficult to identify using a phone-based drive-test tool. However, identifying the base station which is the source of the interference can be difficult and time consuming without the use of identification methods that rely on a receiver-based drive-test tool capable DVCC decode. The methods which have been presented for interferer identification can save time and lead to significant voice quality enhancement in IS-136 TDMA wireless networks.

We offer application notes that span many of today's RF network issues:

- *Optimizing your CDMA Wireless Network Today and Tomorrow. Using Drive-Test Solutions Application Note-1345* (literature number 5968-9916E).
- *Optimizing your GSM Network Today and Tomorrow. Using Drive-Testing to Troubleshoot Coverage, Interference, Handover Margin and Neighbor Lists. Application Note-1344* (literature number 5980-0218E)

For specific examples of how the Agilent Technologies drive-test solutions are used to solve optimization problems:

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