Spurious Emission and Antenna Measurement on Twinkling Antennas for Handheld GSM Mobiles

Radio Technology
& Compatibility Group

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1. INTRODUCTION

1.0.1. Reports from Mobile Phone companies, using the 1800 MHz band, have highlighted cases of interference from mobile phones using the 900 MHz band. The emission of spurious radiation, through Twinkling antennas, being the suspected cause.

1.0.2. This project involved ascertaining whether there were any changes to the transmitted output power levels at the fundamental, second and third harmonic frequencies when each of two Twinkling antennas, supplied by the project sponsor, were substituted for the manufacturers original antenna

2. ABSTRACT

2.0.1. A recent innovation introduced to the mobile phone market is the Twinkling antenna. These antennas incorporate one or more Light Emitting Diodes (LEDs). The LEDs are intended to illuminate when the Mobile Station (MS) is transmitting.

2.0.2. It has been suggested that the non-linear characteristics of the LEDs will cause a transmitting Twinkling antenna to radiate harmonics. It has been further suggested that the receiver performance of the MS will be affected.

2.0.3. This report documents the measurements obtained when testing a typical 900 MHz GSM Mobile Phone using its original antenna and two Twinkling antennas.

2.0.4. A previous test, performed by Telia AB (document: SMG2 1526/99), simulated the MS being used against the head and in an enclosed (office size) space. These tests simulate the MS being used in a semi hands-free situation (held away from the body) and in an open-air environment. This report supports the findings of Telia AB.

2.0.5. The first transmitter tests show that with the original antenna there is no significant output at the second (1800 MHz) and third (2700 MHz) harmonics. The ERP of both signals being below –70 dBm. With one of the Twinkling antennas, however, the second harmonic's Effective Radiated Power (ERP) rose to –26.0 dBm. This figure exceeds the recommended maximum level, as specified by ETS 300 577 [(3)], of –30 dBm. The third harmonic of the other Twinkling antenna rose to –42.7 dBm ERP. The ERP of both Twinkling antennas, at the fundamental frequency, dropped by 4.5 dB on average. The ERP of the twinkling antennas was not sufficient, during these tests, to illuminate the LEDs.

2.0.6. The second transmitter tests involved the MS power at the fundamental frequency, using the Twinkling antennas, being increased to approximately 22 dBm (almost recovering the 4.5 dB loss observed in the first tests). The subsequent harmonic emissions from both Twinkling antennas exceeded the recommended maximum level of –30 dBm as specified by ETS 300 577 [(3)]. The ERP from the twinkling antennas was sufficient, during these tests, to illuminate the LEDs.

2.0.7. The third transmitter tests involved the MS being increased to full power (32 dBm). The subsequent harmonic emissions from both Twinkling antennas exceeded the recommended maximum level of –30 dBm as specified by ETS 300 577[(3)]. The ERP from the twinkling antennas was sufficient, during these tests, to illuminate the LEDs also.

2.0.8. The receiver tests show that, with the Twinkling antennas fitted, the received signal level at the MS antenna socket was reduced by between 4 to 5 dB.

3. TRANSMIT TESTS (ONE)

3.0.1. This test assesses the change in emission levels when the Twinkling antennas were used as a replacement for the manufacturer's original. The output power of the MS was not sufficient to illuminate the LEDs within the Twinkling antennas.

3.0.2. Before any measurements could be performed it was necessary to 'establish a call' between the Base Transceiver Station (BTS) System Simulator (SS), in this case a Rohde & Schwarz CMD 53, and the Mobile Station (MS). This procedure is covered in the appendices.

3.1. Method

3.1.1. The MS was set to transmit at Power Level 10. This is 22 dBm when using its original antenna.

3.1.2. The Effective Radiated Power (ERP) of the fundamental frequency, for each antenna, was established by measuring it through a vertically polarised tuned dipole. In order to ensure that the receiving dipole was in the far field it was placed at a distance of four metres from the MS. The peak signal was established by rotating the turntable on which the MS was placed(1). The signal level of the radiated second and third harmonic frequencies, for each antenna, was established by measurements with a vertically polarised horn antenna. In order to ensure that the receiving horn was in the far field, but still near enough to be able to measure the harmonics, it was placed at a distance of one metre(2) from the MS. No harmonics being detectable by the spectrum analyser at distances greater than one metre. Indeed, the MS needed to be much closer to the horn in order for the harmonics radiated by the manufacturers original antenna to be detected – the tabulated results being an extrapolation of those measurements. The peak signal strengths of the harmonics were established by rotating the turntable in all cases(1).

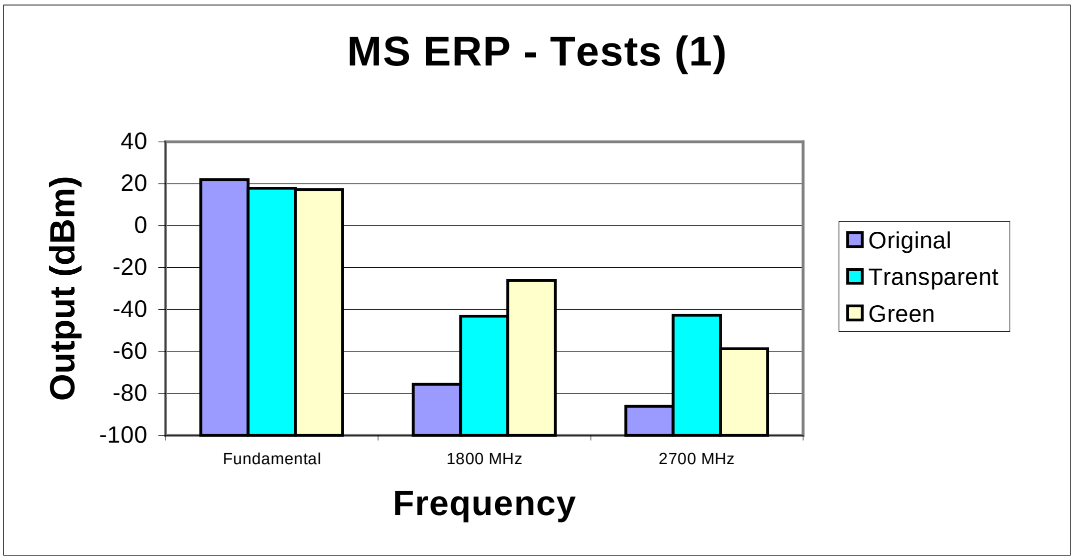
3.1.3. The ERPs of the MS were established by using the Substitution Method. This technique is described in the appendices.

3.2. Results

Transmit Tests (One)					
Transmitted Power - by substitution					
Antenna	Fundamental	1800 MHz		2700 MHz	
	(dBm)	(dBm)	(dBc)	(dBm)	(dBc)
Original	22.0	-75.7	-97.7	-86.2	-108.2
Transparent	17.8	-43.2	-61.0	-42.7	-60.5
Green	17.1	-26.0	-43.1	-58.7	-75.8

Table 1: ERP of antennas – Transmit Tests (1)

Note: Document ETS 300 577(3) dictates that the ERP of spurious emissions shall remain below a maximum level of –30 dBm.



Graph 1: ERP of antennas – Transmit Tests (1)

3.2.1. Analysis – fundamental frequency

3.2.1.1. These results indicate that Twinkling antennas have a significant effect on the ERP, at the fundamental frequency, of the host MS. The ERP being reduced by 4.2 to 4.9 dB, with respect to the ERP of the manufacturers original antenna, in this case.

3.2.1.2. In a working environment the Base Transceiver Station (BTS) would request that the MS increase its power to the antenna by these amounts in order that it should transmit the required ERP. This increase in power usage would have the effect of reducing the, daily and long term, battery life of the MS. The increase in power would also result in an increase in the level of the harmonics shown in table 1.

3.2.1.3. The Transmitter Tests (2) section examines the increased harmonic levels, using the Twinkling antennas, when the fundamental frequency's ERP is increased to 22 dBm.

3.2.2. Analysis – harmonic frequencies

3.2.2.1. Document ETS 300 577 (GSM 05.05, version 4.22.2, section 4.3.3) requires that the harmonically emitted 'power measured shall be no more than –30 dBm in the frequency band 1.0 to 12.75 GHz'.

3.2.2.2. The ERP at the second harmonic of the 'green' Twinkling antenna exceeds this maximum figure by 4 dB.

3.2.2.3. With an ERP of 17.1 dBm at the fundamental frequency, the transparent antenna's harmonic emissions, for these tests, were within specification. See Transmit Tests (2).

4. TRANSMIT TESTS (TWO)

4.0.1. The transmit efficiency of the Twinkling antennas are less than the manufacturers original antennas. In a working environment this will require the MS to increase its power. This is so that the BTS will receive it at the same level as if the MS had a manufacturers original antenna fitted.

4.0.2. These tests measure the spurious emissions when, with the replacement antennas fitted, the output power of the MS is increased so as to radiate the same, almost, fundamental signal level as that when the manufacturer's original antenna was used.

4.0.3. It should be noted that the ERP (approximately 22 dBm) of the MS during these tests was sufficient to illuminate the LEDs within the Twinkling antennas.

4.1. Method

4.1.1. Communication between the CMD 53 and the MS was re-established.

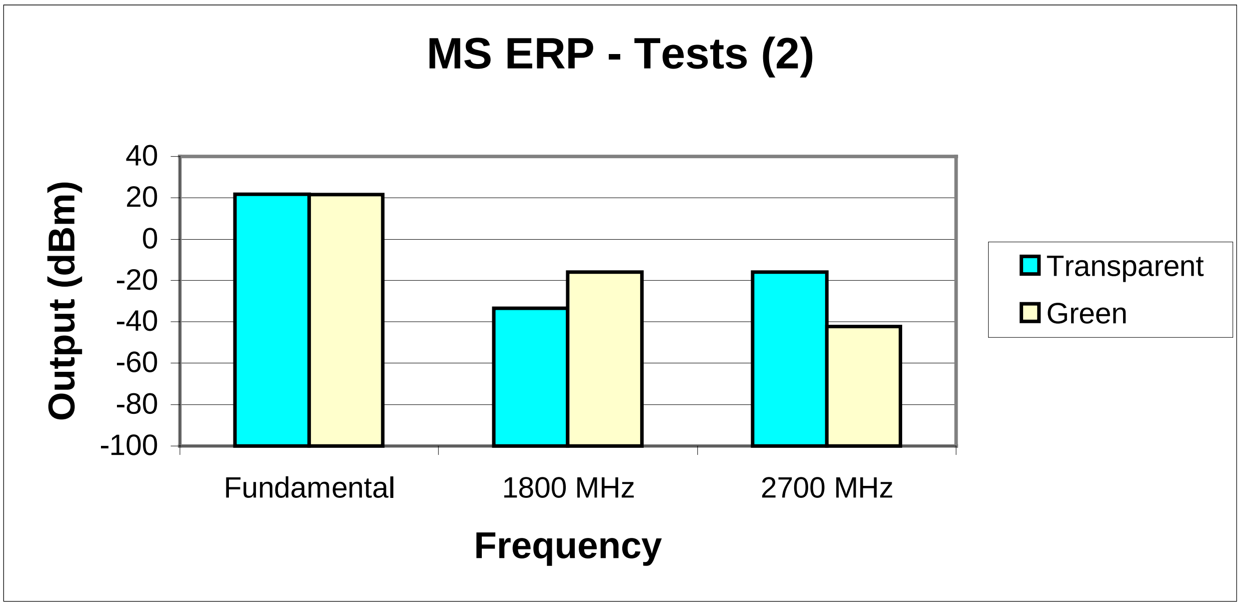
4.1.2. From within the 'Call Established' menu on the CMD 53 the output power of the MS was increased until the ERP, using the replacement antennas, became 21.7 dBm (transparent antenna) and 21.5 dBm (green antenna). The harmonic emissions were re-measured using the same methods and test equipment as previously.

4.2. Results

Transmit Tests (Two)					
Transmitted Power - by substitution					
Antenna	Fundamental	1800 MHz		2700 MHz	
	(dBm)	(dBm)	(dBc)	(dBm)	(dBc)
Transparent	21.7	-33.3	-55.0	-16.1	-37.8
Green	21.5	-16.1	-37.6	-42.2	-63.7

Table 2: ERP of antennas – Transmit Tests (2)

Note: Document ETS 300 577[3] dictates that the ERP of spurious emissions shall remain below a maximum level of –30 dBm.



Graph 2: ERP of antennas – Transmit Tests (2)

4.2.1. Analysis – harmonic frequencies

4.2.1.1. The ERP of the second harmonic of the 'Transparent' antenna increased to –16.1 dBm. This level exceeds the ETS 300 577 [3] maximum by 13.9 dBm.

4.2.1.2. The ERP of the third harmonic of the 'Green' antenna increased to –16.1 dBm. This level also exceeds the ETS 300 577 [3] maximum by 13.9 dBm.

5. TRANSMIT TESTS (THREE)

5.0.1. The previous test established that the harmonics, using Twinkling antennas, exceed the ETS 300 577 [3] requirement when the ERP of the fundamental frequency is limited to 22 dBm. In these tests the output power of the MS is increased to its maximum (32 dBm) and the corresponding fundamental and harmonic ERPs are measured.

5.0.2. The ERP of the MS was sufficient to illuminate the LEDs within the Twinkling antennas during these tests also.

5.1. Method

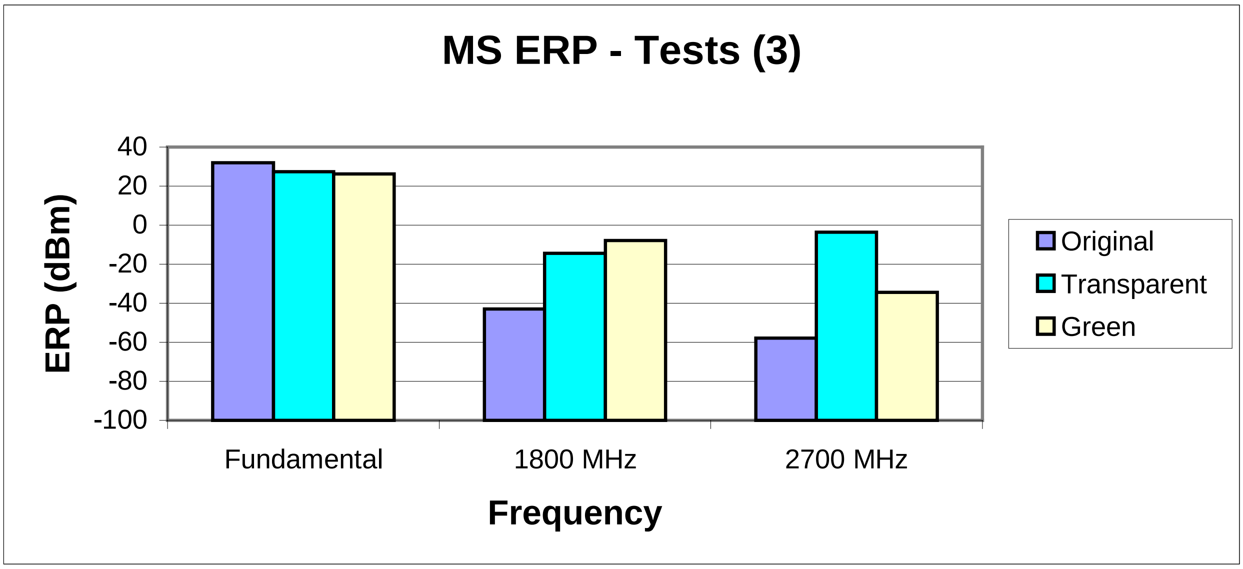
5.1.1. Communication between the CMD 53 and the MS was re-established. From within the ‘Call Established’ menu on the CMD 53 the output power of the MS was increased to maximum (power level 5). The harmonic emissions were re-measured using the same methods and test equipment as previously.

5.2. Results

Transmit Tests (Three)					
Transmitted Power - by substitution					
Antenna	Fundamental	1800 MHz		2700 MHz	
	(dBm)	(dBm)	(dBc)	(dBm)	(dBc)
Original	31.8	-42.9	-74.7	-58.0	-89.8
Transparent	27.3	-14.3	-41.6	-3.6	-30.9
Green	26.3	-7.9	-34.2	-34.4	-60.7

Table 3: ERP of antennas – Transmit Tests (3)

Note: Document ETS 300 577[3] dictates that the ERP of spurious emissions shall remain below a maximum level of –30 dBm.



Graph 3: ERP of antennas – Transmit Tests (3)

5.2.1. Analysis – fundamental frequency

5.2.1.1. These results show that, at the fundamental frequency, the replacement antennas have similar losses when compared with the manufacturers original antenna. The losses being 4.5 to 5.5 dB, compared with the manufacturers original antenna, in this case.

5.2.2. Analysis – harmonic frequencies

5.2.2.1. The ERP of the second harmonic of the 'Transparent' antenna increased to –14.3 dBm. The ERP of the third harmonic increased to –3.6 dBm. Both of these levels exceed the ETS 300 577(3) maximum.

5.2.2.2. The ERP of the second harmonic of the 'Green' antenna increased to –7.9 dBm. This level exceeds the ETS 300 577(3) maximum. The ERP of the third harmonic remained below.

6. RECEIVER TESTS

6.0.1. The CMD 53 GSM Test Set has a section within its ‘Call Established’ menu which displays the reported strength by the MS, at its antenna socket, of the received signal strength of the System Simulator’s transmitter.

6.1. Method

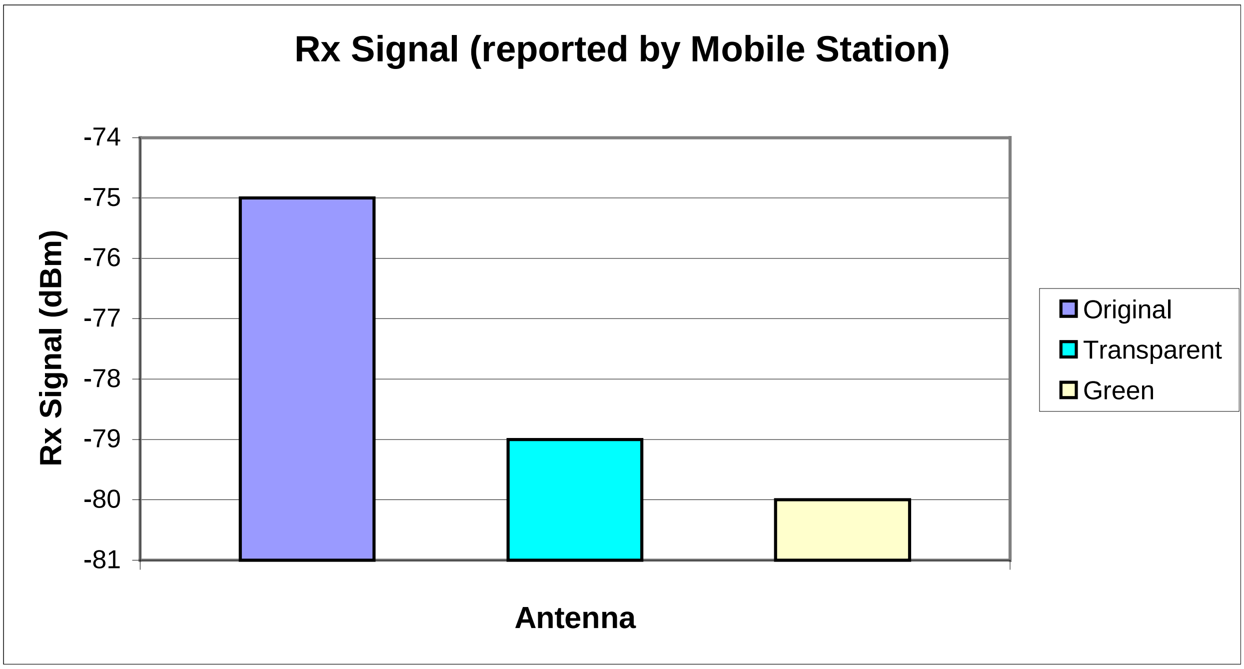
6.1.1. The receiver measurements were conducted within a G-TEM™ cell (DTI 2604). The configuration of the call establishment test equipment was very similar to that used for the transmitter tests. The test equipment set-up is shown in the appendices.

6.1.2. The MS was placed in the centre of the G-TEM™ cells working volume. When the call was established a fixed field strength within the G-TEM™ cell was produced. The resulting signal strength at the antenna socket was measured, by the MS, and displayed on the CMD 53. This procedure was repeated for each of the three antennas.

6.2. Results

Antenna	**Strength (dBm)**
Original	-75
Transparent	-79
Green	-80

Table 4: Received Signal Strengths.



Graph 4: Received Signal Strengths.

6.2.1. Analysis

6.2.1.1. These results indicate that Twinkling antennas have a significant effect on the sensitivity of the host MS. The signal to the antenna socket being reduced by 4 to 5 dB, with respect to the manufacturer's original antenna, in this case.

6.2.1.2. In a real environment the Base Transceiver Station (BTS) would need to increase its power by these amounts in order for the MS to maintain the required Signal to Noise ratio. This increase in power will have a knock-on effect to the Interference levels to adjacent GSM clusters.

7. GLOSSARY

BPF	Band Pass Filter
BTS	Base Transceiver Station
dB	Deci-Bel - a logarithmic power ratio (‘gain’)
- dB	minus dB equals attenuation (‘loss’)
dBc	dB gain - referenced to the output of the fundamental frequency’s ‘carrier’ power.
dBd	dB gain - referenced to the radiation pattern of a ‘dipole’ antenna
dBi	dB gain - referenced to the radiation pattern of an ‘isotropic’ antenna
dBm	dB gain - referenced to one ‘milli-Watt’(eg 30 dBm = 1Watt)
DTI nnnn	A unique RTCG equipment identification number
DUT	Device Under Test
EIRP	Effective Isotropic Radiated Power
GSM	Global System for Mobile communications
G-TEM™	Giga Hertz – Transverse Electro-Magnetic cell. A particular type of test chamber.
MS	Mobile Station (Mobile Phone)
SA	Spectrum Analyser
SG	Signal Generator

8. REFERENCES

1 ETS 300 607-1 (GSM 11.10-1 version 4.23.1) Section: 12.2.1.4.2, Sub-section b
2 ETS 300 607-1 (GSM 11.10-1 version 4.23.1) Section: 12.2.1.4.2, Sub-section c, NOTE 2:
3 ETS 300 577 (GSM 05.05 version 4.22.2) Section: 4.3.3

APPENDIX 1

Test Equipment

1.1. Calibrated

R&S CMD 53	GSM System Simulator	- DTI 2513
HP 8563E	Spectrum Analyser	- DTI 2575
HP 4426B	Signal Generator	- DTI 2855
G-TEM™ 5311	Chamber	- DTI 2604
Anritsu MP651A	Calibrated Dipole	- DTI 0160
Anritsu MP651A	Dipole	- DTI 0159
QPA Anthor QA 218-N	Calibrated Horn	- DTI 0481
QPA Anthor 93006	Calibrated Horn	- DTI 2108
QPA Anthor QA 218-N	Horn	- DTI 0480
HP 8491B	6dB Attenuator	- DTI 2854
MCL ZAPD-21	6 dB Splitter/Comb.	- DTI 2260
MCL ZAPD-21	6 dB Splitter/Comb.	- DTI 2260
HP 8447D	26 dB Amplifier	- DTI 0574
K&L 6BT-800/900-1-N/N	Band Pass Filter	- DTI 2613
Texscan 5VF500/1000-2-AA	Band Pass Filter	- DTI 0448
K&L 5BT-1000/2000-5N	Band Pass Filter	- DTI 0636
N to N-type cable	(calibrated)	- DTI 2879
N to N-type cable	(calibrated)	- DTI 2882

1.2. Non-calibrated

Mobile Phone:

Twinkling antenna (transparent body) – no details supplied.
Twinkling antenna (green body) – no details supplied.

APPENDIX 2

Call Establishment Procedure – Transmit tests

2.1. Before any measurements could be performed it was necessary to configure the Rohde & Schwarz CMD 53 GSM System Simulator (SS) to establish a connection with the Mobile Station (MS). The bare bones CMD 53, as supplied, is designed to connect directly to the antenna socket of a Device Under Test (DUT) using the, input/output, N-type connector on its front panel. To communicate off-air requires the B-30 option. Without it the CMD 53 lacks receiver sensitivity.

2.2. This problem was overcome by first splitting the signals from the N-type connector into separate transmit and receive routes. A 26dB amplifier was then introduced to the received signal path.

2.3. The signals to and from the MS were coupled using dipoles. To increase isolation the dipoles were cross-polarised by off-setting them by 45 degrees either side of vertical.

2.4. Antenna re-radiation problems were removed by inserting Band Pass Filters (BPF). The BPFs were tuned to the respective MS transmit or receive frequencies. See figure 1 below.

2.5. The MS was pre-set to transmit on the uplink of Channel 37 (MS transmit = 897.4 MHz, MS receive = 942.4 MHz). The System Simulator's Control channel was set to Channel 42 (SS transmit = 943.4 MHz, SS receive = 898.4 MHz).

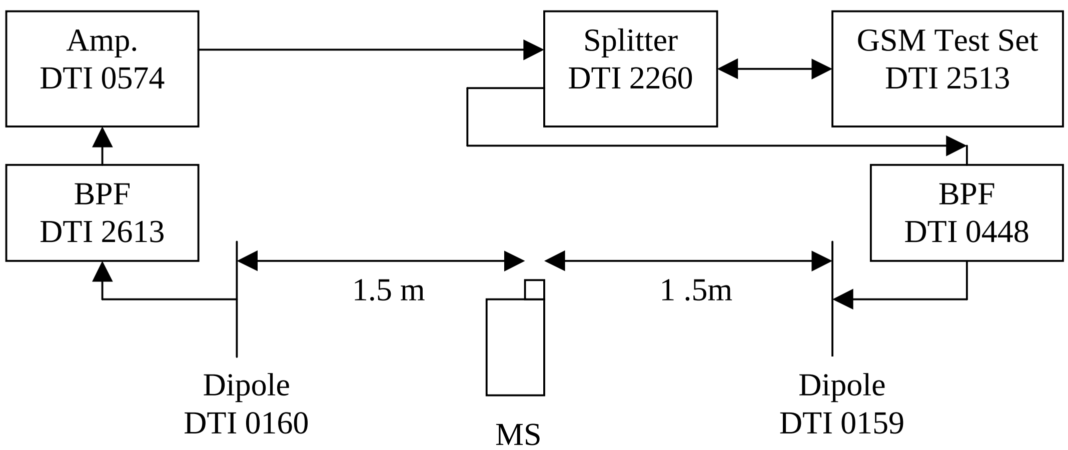


Fig. 1: Mobile Station Call Establishment method.

APPENDIX 3

Call Establishment Procedure – Receiver tests

3.1. The receiver measurements were conducted within a G-TEM™ cell (DTI 2604). The configuration of the call establishment test equipment was very similar to that used for the transmitter tests. A 6dB combiner was required to re-connect the transmit and receive paths prior to connection to the G-TEM™ cell's end connector. An additional amplifier (DTI 1298) and a BPF (DTI 0636) were required to compensate for the increased receive path losses. See figure 2 below.

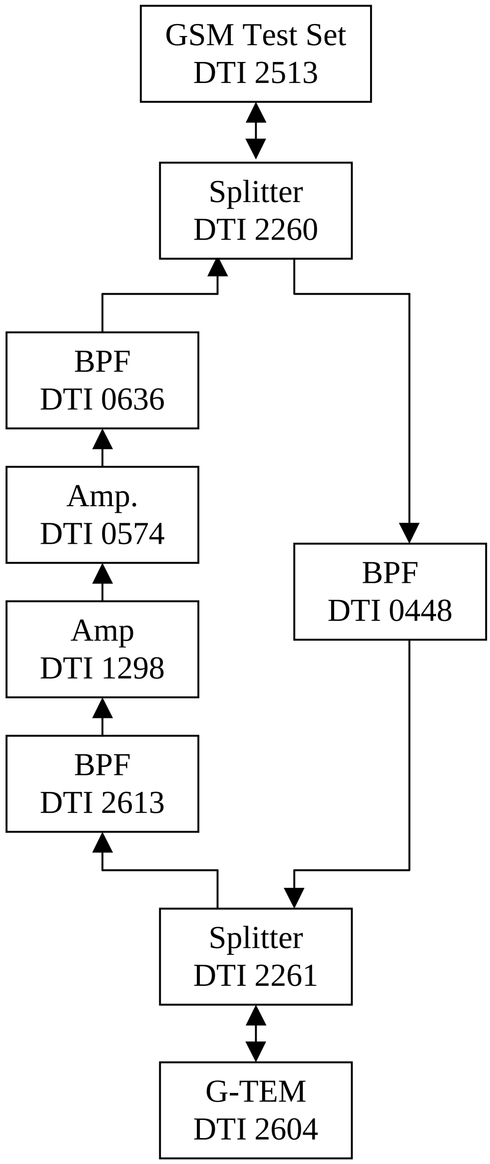


Fig.2: Receiver test configuration.

APPENDIX 4

Substitution Method

4.1. The radiated fundamental frequency from the MS is detected by the tuned dipole (DTI 0326) and fed to a Spectrum Analyser (SA), see figure 3. The distance given in the diagram is that used for this project. The measurement on the SA is recorded.

4.2. A tuned dipole (DTI 0160), plus 6 dB attenuator, is then connected to a Signal Generator (SG), see figure 4. The output of the SG is varied until the same reading is obtained on the SA.

4.3. The 6dB attenuator is then disconnected from the antenna and connected directly to the SA, see figure 5. The SA reading, using a unity-gain dipole, represents the ERP of the MS.

4.4. The radiated second harmonic frequency from the MS is detected using, in this case, a broadband horn (DTI 0480) and fed to the Spectrum Analyser (SA), see figure 3. The distance given in the diagram was that used for this project. The measurement on the SA is recorded.

4.5. Another broadband horn (DTI 0481), plus 6 dB attenuator, is then connected to a Signal Generator (SG), see figure 4. The output of the SG is varied until the same reading is recorded on the SA.

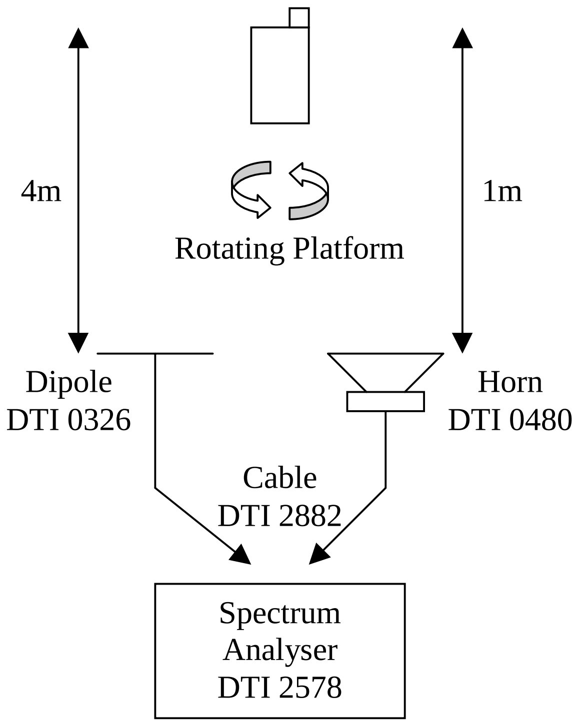


Fig. 3:

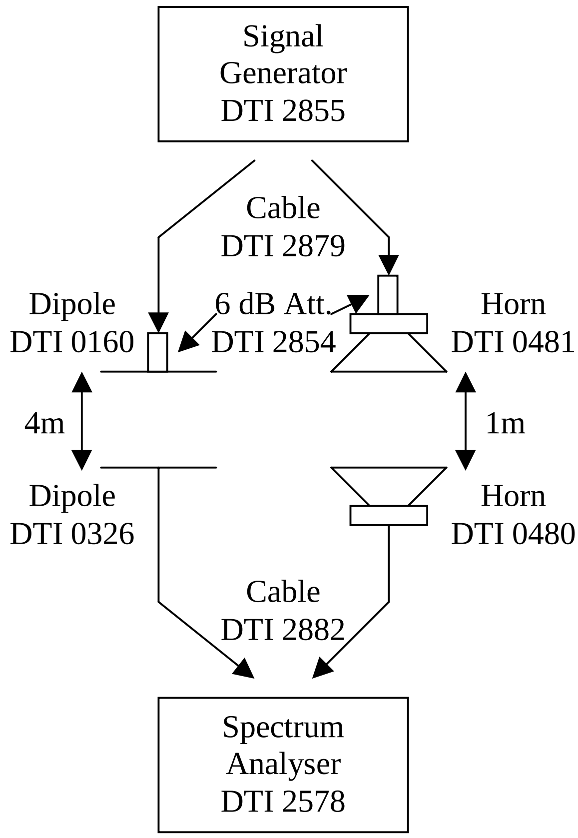


Fig.4:

4.6. The 6dB attenuator is disconnected from the antenna and connected directly to the SA, see figure 5. The SA reading plus the gain of the horn (DTI 0481) represents the ERP of the MS.

4.7. Sections 4.4 to 4.6 are repeated for the third harmonic measurements.

4.8. The harmonic frequency measurements need to have the gain of the horn antenna specified in dBd. In these tests the gain of the horn antenna (DTI 0481) at the second and third harmonic frequencies were 6.4 and 9.7 dBd respectively.

4.9. The 6 dB attenuator (DTI 2854) is fitted to the rear of the dipole and horn to ensure that the SG saw the correct impedance at the antenna and should there have been any reflections they would have undergone at least 12 dB of attenuation before being radiated.

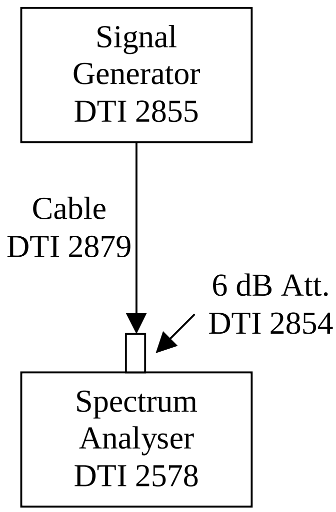


Fig.5: