VLA-VLBA Interference Memo # 38

VLBA-PT Station Building Shielding Test Report Addendum: Shielding Interpolation and Extrapolation into Untested Frequency Regions

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Abstract

VLBA-PT Station Building shielding data collected and reported on in June 2009 is interpolated between 100 – 900 MHz, and extrapolated down to 50 MHz and up to 20 GHz.

1. Overview:

Architectural shielding tests of the Pie Town (PT) NM VLBA Station Building were performed in June of 2009 in order to determine additional shielding requirements for the new Digital Back End (DBE) rack, as well as new PC, monitor, and Local Area Network (LAN) distribution devices. The 2009 tests were performed at 100, 300, 600, and 900 MHz, in order to match the frequencies used in the 1987 shielding tests performed by Oty, et. al. (as documented in VLBA Array Memo # 596).

Subsequent analysis has shown the need to provide estimated shielding values between and above the 4 measurement frequencies in order to provide continuous plots of power levels, detrimental emission levels, and shielding requirements. This report addendum explains the interpolation and extrapolation methodologies, and provides multi-order polynomial equations which may be used to calculate approximate shielding levels for frequencies from 50 MHz to 20 GHz at any necessary frequency resolution.

2. June 2009 Empirical Data Baseline:

Linearizing then averaging[1] the shielding data collected during the June 2009 tests at VLBA-PT (see **Figure 1**, **2**, and **3**, and the main body of the "VLBA-PT Station Building Shielding Test Report"), generates average shielding values for rooms 100, 103, and 104 in the direction of the VLBA antenna (bearing 180° ±45°) for each of the 4 test frequencies as:

TABLE 1: AVERAGED SHIELDING TEST DATA

ROOM	100 MHz	300 MHz	600 MHz	900 MHz
#	dB	dB	dB	dB
100	11.8	15.1	29.6	39.2
103	19.4	21.5	31.2	41.5
104	18.7	22.3	27.9	34.3

[1] For each of the 4 test frequencies, the previously calculated shielding values in dB for the 3 bearings most nearly pointing toward the VLBA antenna were converted to linear, arithmetically averaged, then converted back into dB values.

3. Interpolation Methodology:

The averaged test data of **Table 1** was plotted from the data analysis MS-Excel spreadsheet. For each of the 3 rooms, Excel was used to create a trendline from 50 to 1000 MHz using a 5th order polynomial, and display the equation for the trendline to the maximum precision of the Excel spreadsheet. The high precision does not provide additional accuracy, but prevents the trendline equation from "blowing up" at the frequency extremes. The accuracy of the underlying UHF data is believed to be on the order of ± 10 dB, based on realtime variances seen during the PT test. The averaged shielding factors at 100 and 900 MHz were extended to 50 and 1000 MHz (respectively) in order to provide continuity with extrapolated data (see Extrapolated Methodology section, below). The following 3 equations were produced:

Room 100:
Shielding, 50-1000 MHz (dB) = $0.000000000000165909125008130000f^5$ - $0.000000000442081980472752000000f^4$ + $0.000000322847689400470000000000f^3$ - $0.000016493308871612000000000000f^2$ - $0.002931698457825880000000000000f$ + 11.950173398619600000000000000000

Room 103:
Shielding, 50-1000 MHz (dB) = $-0.000000000000024951670983101100f^5$ - $0.000000000017356618670697900000f^4$ + $0.000000044517515893982000000000f^3$ + $0.000023449588316038800000000000f^2$ - $0.003678675967723880000000000000f$ + 19.519861413223300000000000000000

Room 104:
Shielding, 50-1000 MHz (dB) = $-0.000000000000262264974884124000f^5$ + $0.000000000666811936537874000000f^4$ - $0.000000623793763560365000000000f^3$ + $0.000263979130261028000000000000f^2$ - $0.030048704356582000000000000000f$ + 19.616375994782200000000000000000

The results of the interpolation, with the above equations plotted on top of the trendline are shown in **Figures 4, 5, and 6**, below. These three equations may be used in any spreadsheet analysis where estimated shielding values for any of the three rooms are needed between 50 and 1000 MHz. The variable "f" is the frequency at which a shielding value is required.

4. Extrapolation Methodology:

Previous tests of shielded rack efficacy have shown that shielding values maximize in the high UHF and low L-band region of spectrum[2]. Above that frequency, the increasingly shortened wavelength allows electromagnetic radiation to escape through 1/30th wavelength or larger openings[3]. Below that frequency, longer wavelength resonances, magnetic field penetration, and surface currents can become an increasingly significant factor, compromising shielding integrity. To extrapolate the PT shielding data above 1 GHz, the 900 MHz shielding figure for each room was used as a peak value (See **Table 1**, above), and the Premier shielded rack shielding curve (see

[2] See "Premier Shielded Rack (Type NRAO VLBA DBE) Shielding Test Report", 20090121, D. Mertely, B Waits, for a typical example.
[3] See "Shielding for EMC", Dag Björklöf, Compliance Engineering, 1999 Reference Guide, Pg 4.

Figure 7, below) then normalized to that max[4]. The difference (in dB) between the **Table 1** 900 MHz values and the calculated Premier rack average shielding value from 1-2 GHz was then subtracted from the 1-20 GHz Premier rack shielding curve to generate PT Station Building prototype curves. As in the interpolation case described above, MS-Excel was used to generate a 6th order polynomial describing the curve. Once again note that the high precision of the trendline equations does not provide additional accuracy, but prevents the trendline equation from "blowing up" at the frequency extremes. The accuracy of the underlying rack shielding data is in the order of ± 6 dB. The following 3 equations were produced:

Room 100:
Shielding, 1-20 GHz (dB) = $-0.000083378576801518300000000000f^6$ + $0.005377586024764900000000000000f^5$ - $0.130495486979238000000000000000f^4$ + $1.469509472726640000000000000000f^3$ - $7.492103514626630000000000000000f^2$ + 11.646688338513900000000000000000f + 58.447063306395100000000000000000 – 64.4 + **39.2**

Room 103:
Shielding, 1-20 GHz (dB) = $-0.000083378576801518300000000000f^6$ + $0.005377586024764900000000000000f^5$ - $0.130495486979238000000000000000f^4$ + $1.469509472726640000000000000000f^3$ - $7.492103514626630000000000000000f^2$ + 11.646688338513900000000000000000f + 58.447063306395100000000000000000 – 64.4 + **41.5**

Room 104:
Shielding, 1-20 GHz (dB) = $-0.000083378576801518300000000000f^6$ + $0.005377586024764900000000000000f^5$ - $0.130495486979238000000000000000f^4$ + $1.469509472726640000000000000000f^3$ - $7.492103514626630000000000000000f^2$ + 11.646688338513900000000000000000f + 58.447063306395100000000000000000 – 64.4 + **34.3**

The results of the extrapolation, with the above equations plotted on the same chart are shown in **Figure 7**, below. These three equations may be used in any spreadsheet analysis where estimated shielding values for any of the three rooms are needed between 1 and 20 GHz. The variable "f" is the frequency at which a shielding value is required.

In the future, as additional data points are empirically obtained from new field tests, these equations may be adjusted (as necessary) to accept and account for the new data.

[4] The linearized shielding values from 1 to 2 GHz were arithmetically averaged, then converted back into dB values, generating a 1-2 GHz average shielding figure of 64.4 dB.

Chart Descriptions:

Figure 1: 20090602 test data: shielding from room 100 (the Site Technicians' work room), in the direction of each of the RX positions.

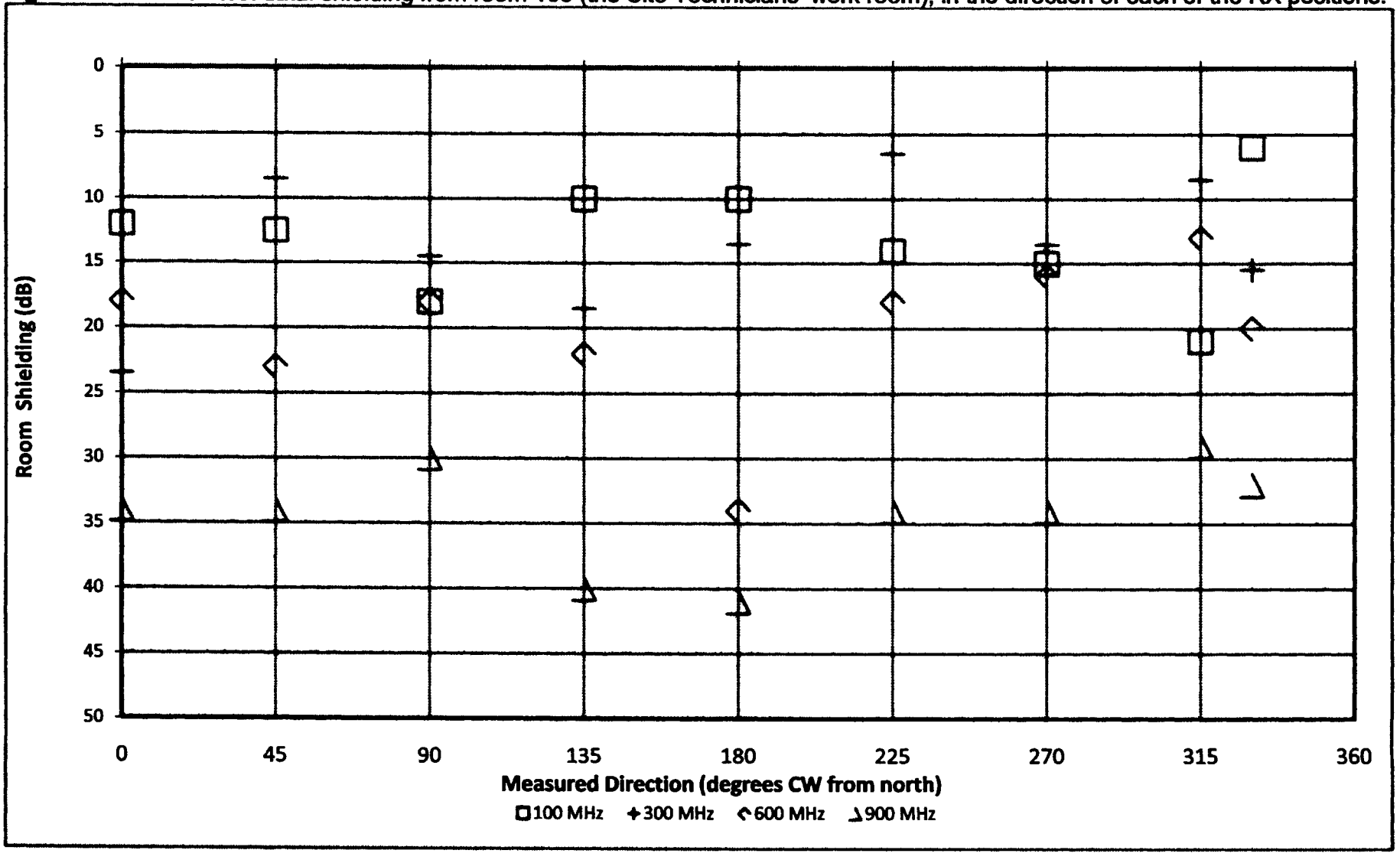

Figure 2: 20090602 test data: shielding from room 103 (the DBE/Recorder room), in the direction of each of the RX positions.

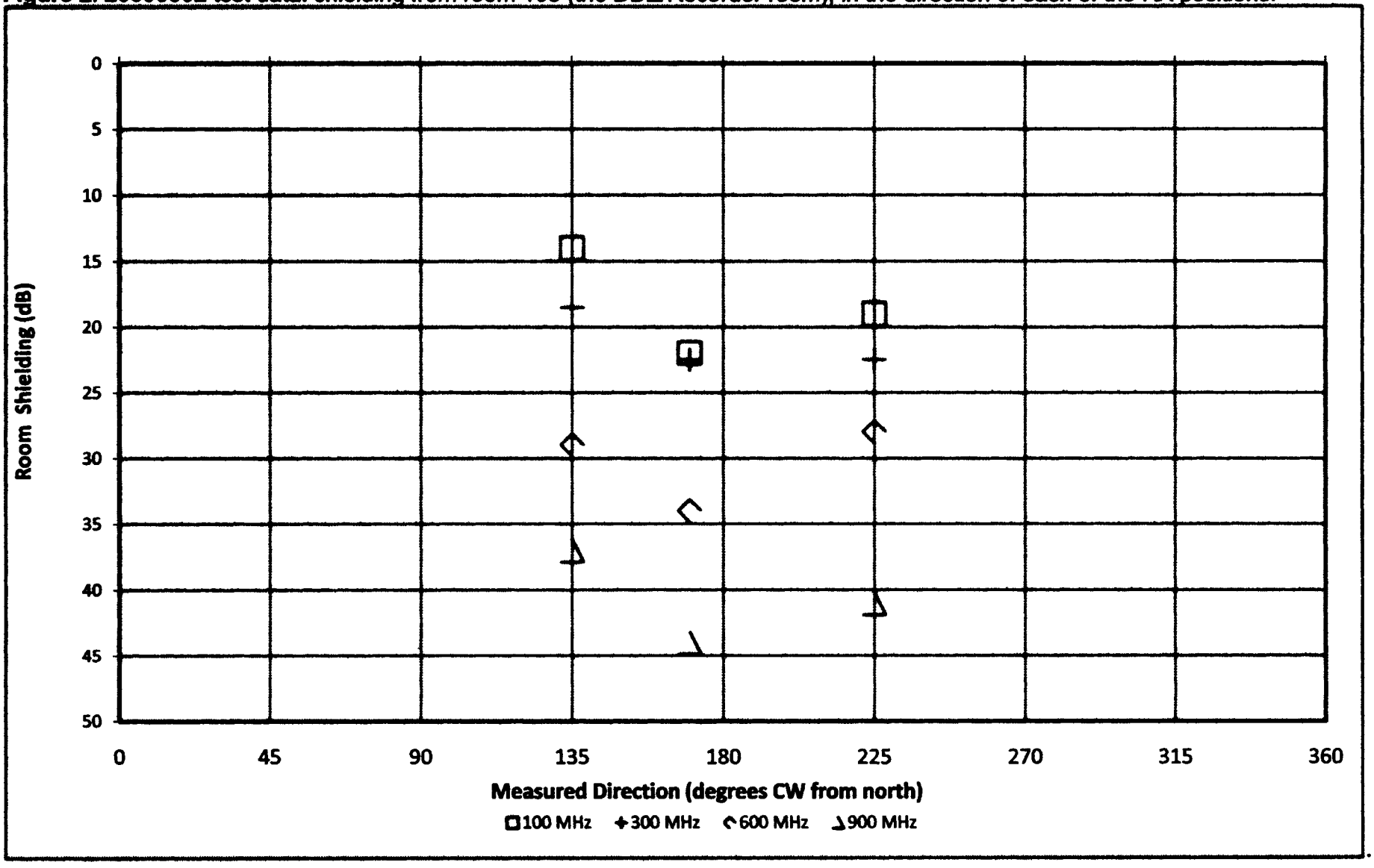

Figure 3: 20090602 test data: shielding from room 104 (the LO/IF/MASER room), in the direction of each of the RX positions.

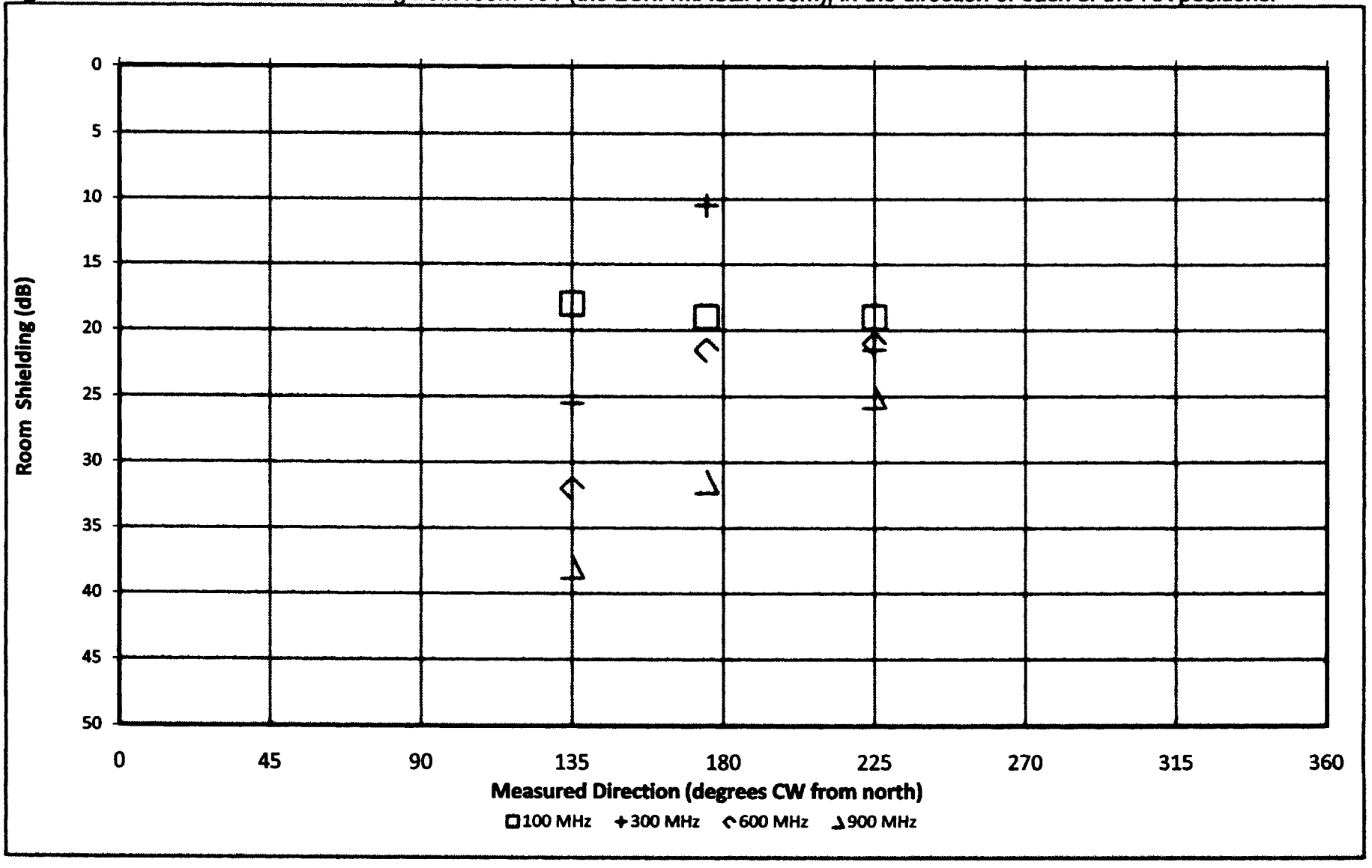

Figure 4: Shielding and shielding trendline vs. frequency from room 100 (the Site Technicians' work room), in the direction of the VLBA antenna.

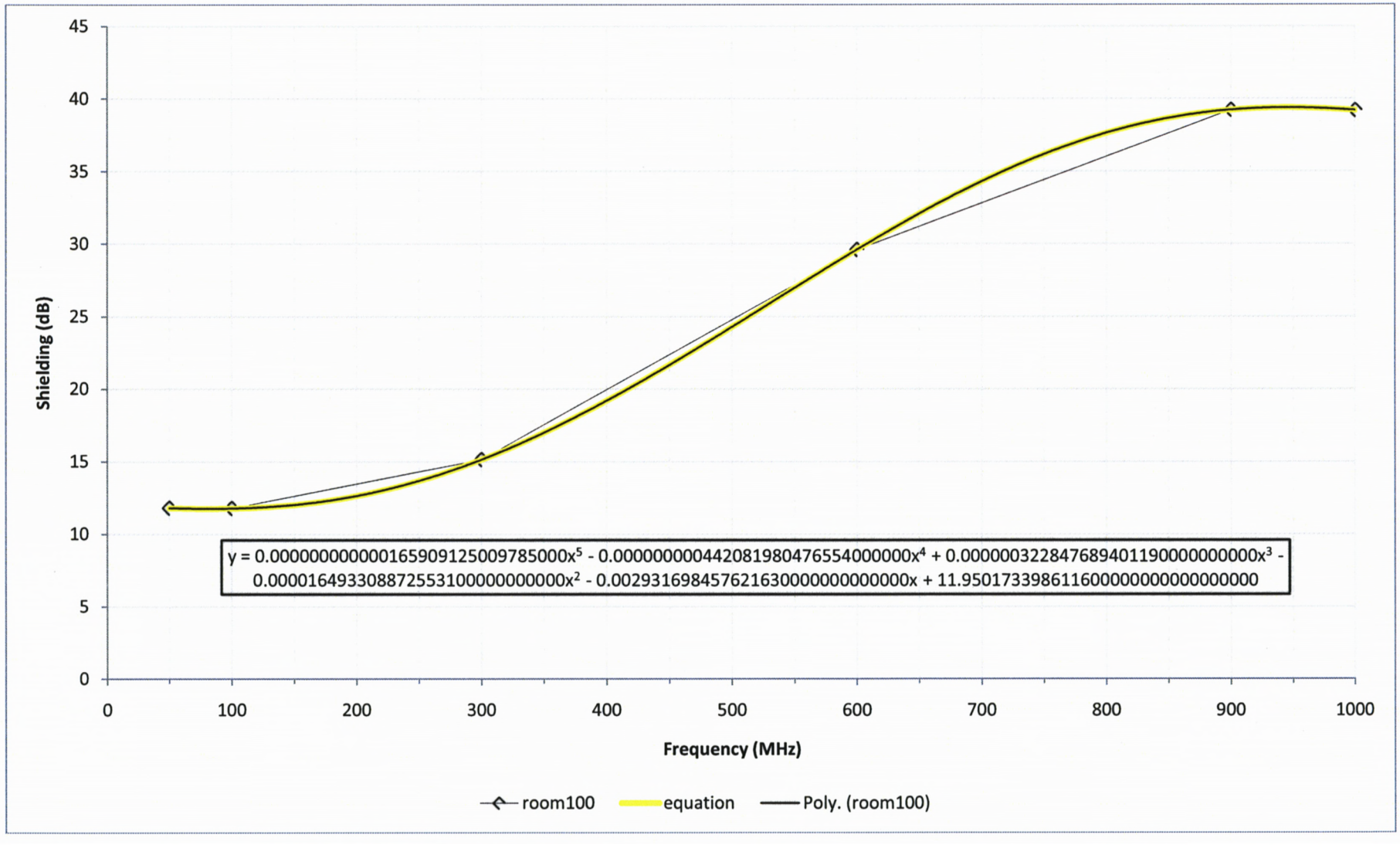

Figure 5: Shielding and shielding trendline vs. frequency from room 103 (the DBE/Recorder room), in the direction of the VLBA antenna.

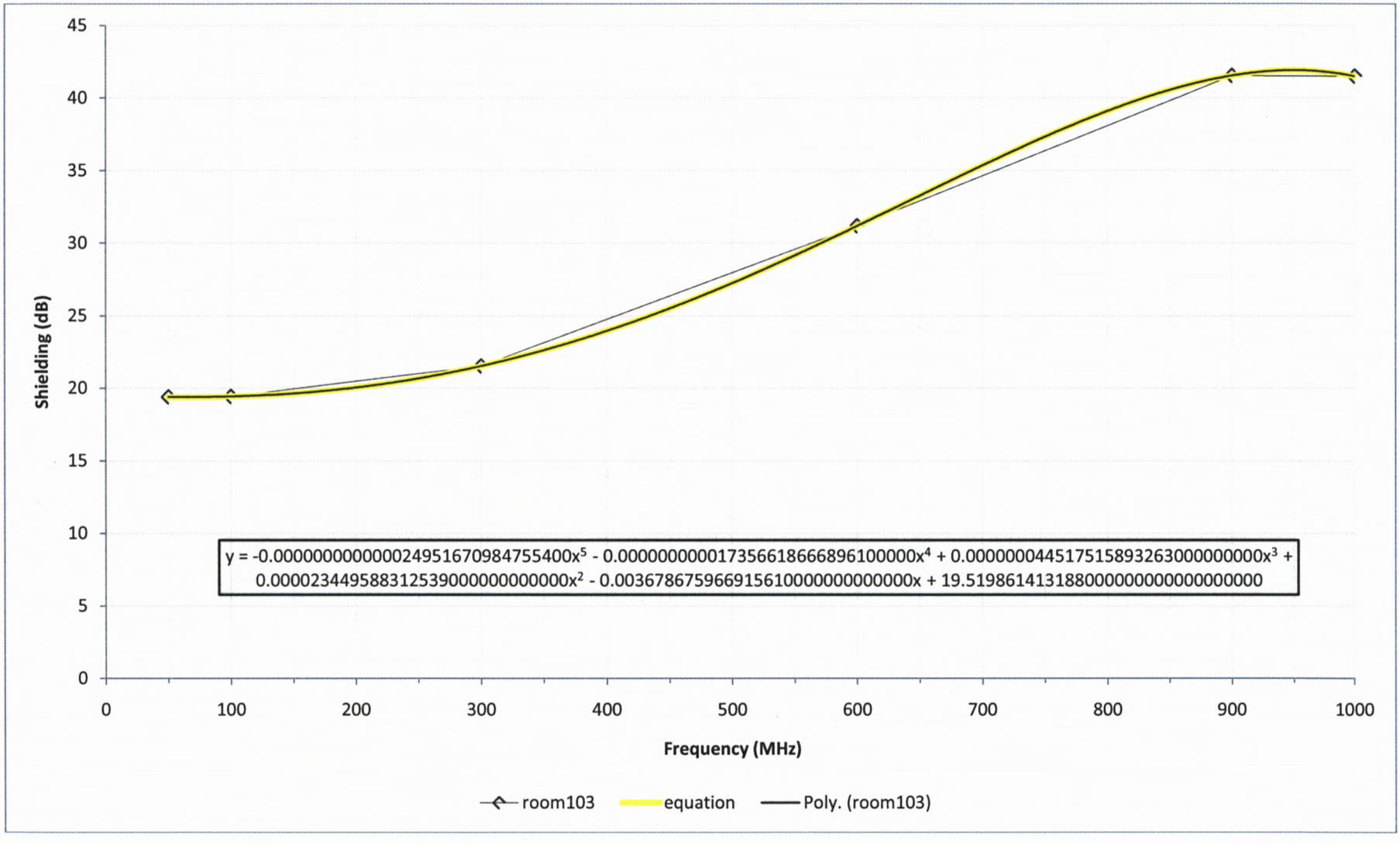

Figure 6: Shielding and shielding trendline vs. frequency from room 104 (the LO/IF/MASER room), in the direction of the VLBA antenna.

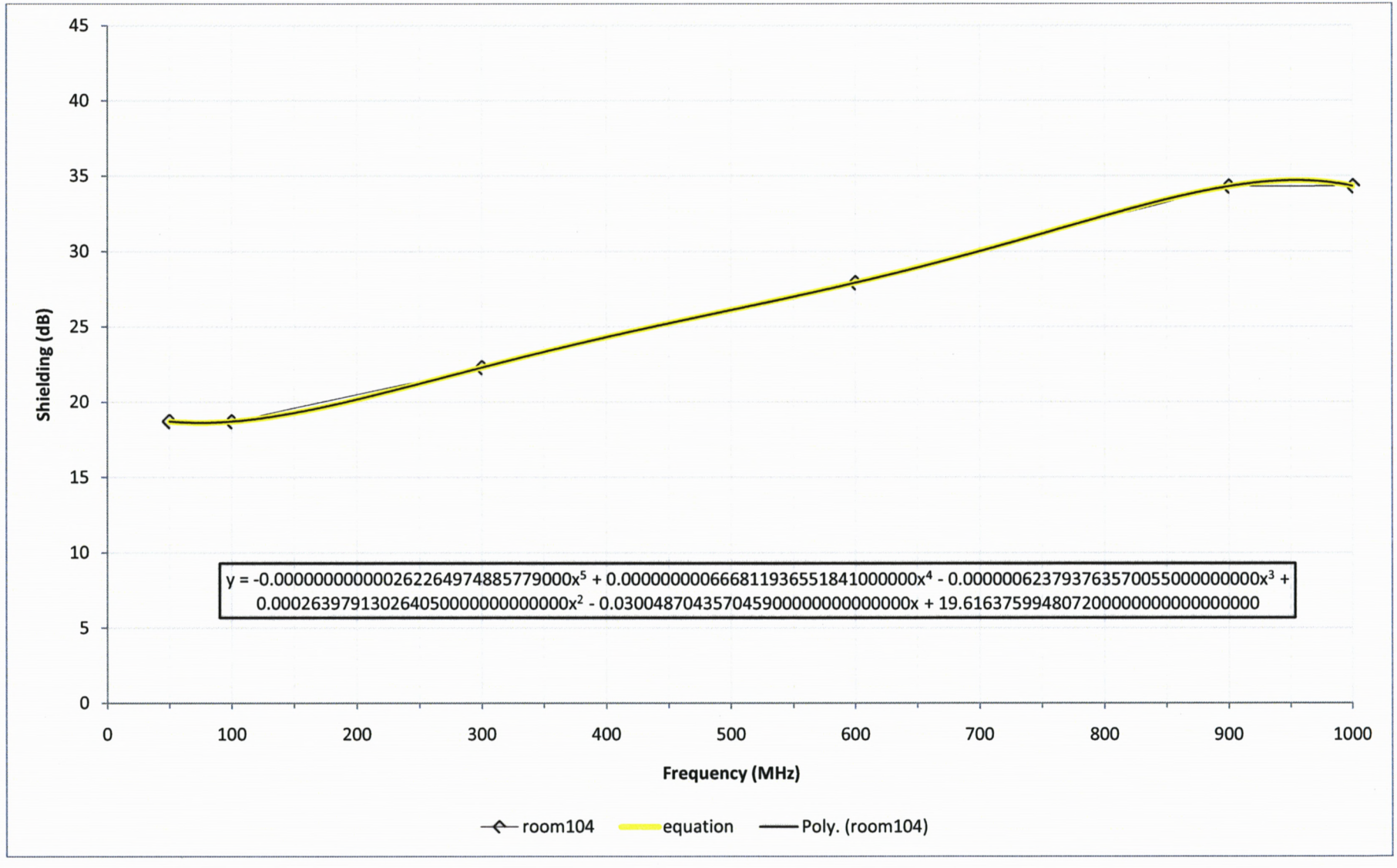

Figure 7: Premier shielded rack 1-20 GHz shielding curve and equation (top) with PT room normalization curves (below) added.