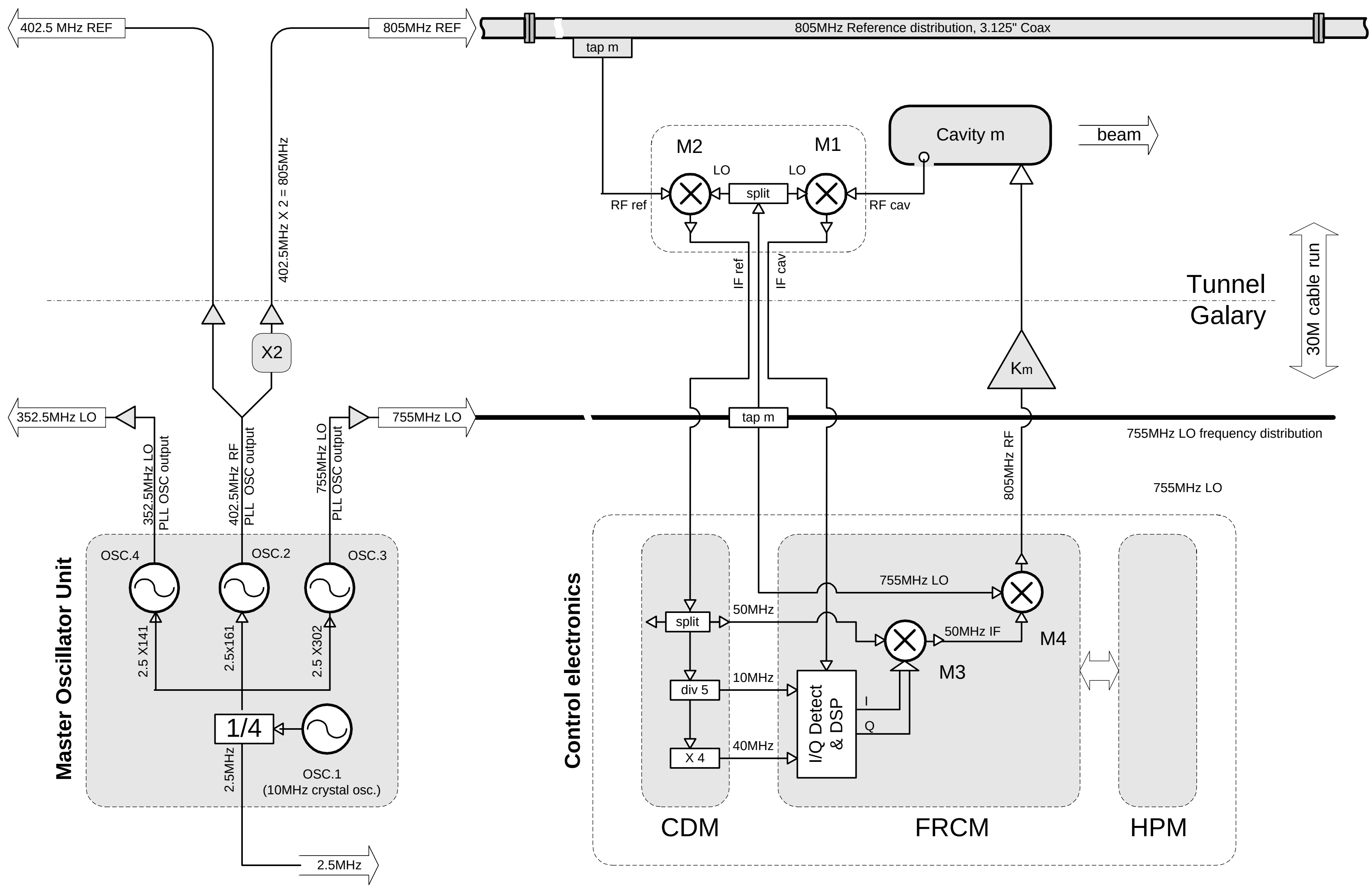
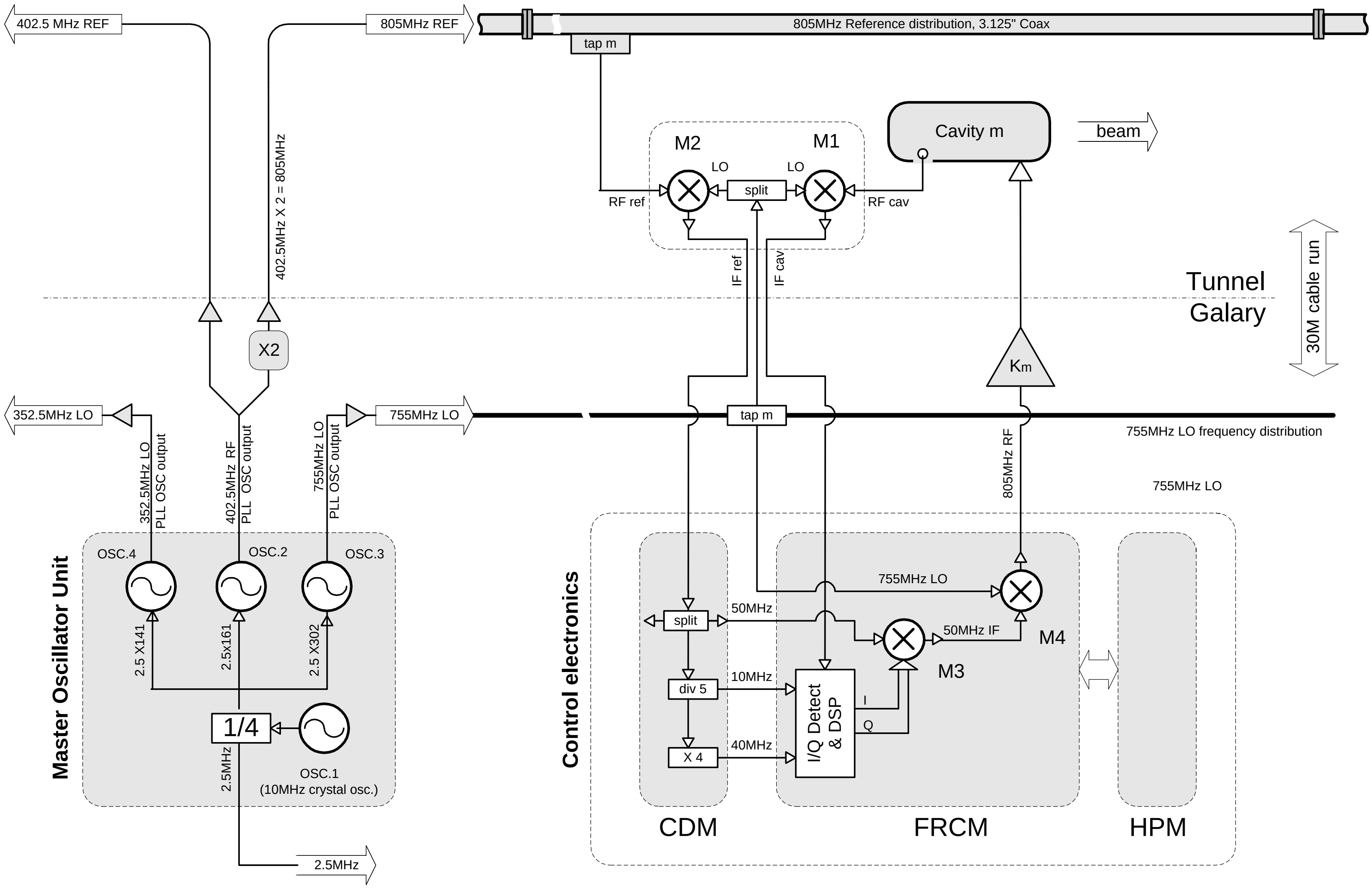
1-1. System Hardware Components - General

1. Referenece sub-system: master osc. Unit, 805/402.5MHz reference dist. line in tunnel, 755/352.5MHz LO dist. line in galary.
2. Control electronics sub-system: Clock-Distrubution Module, Field-Resonance-Control-Module, High-power-Protection-Module



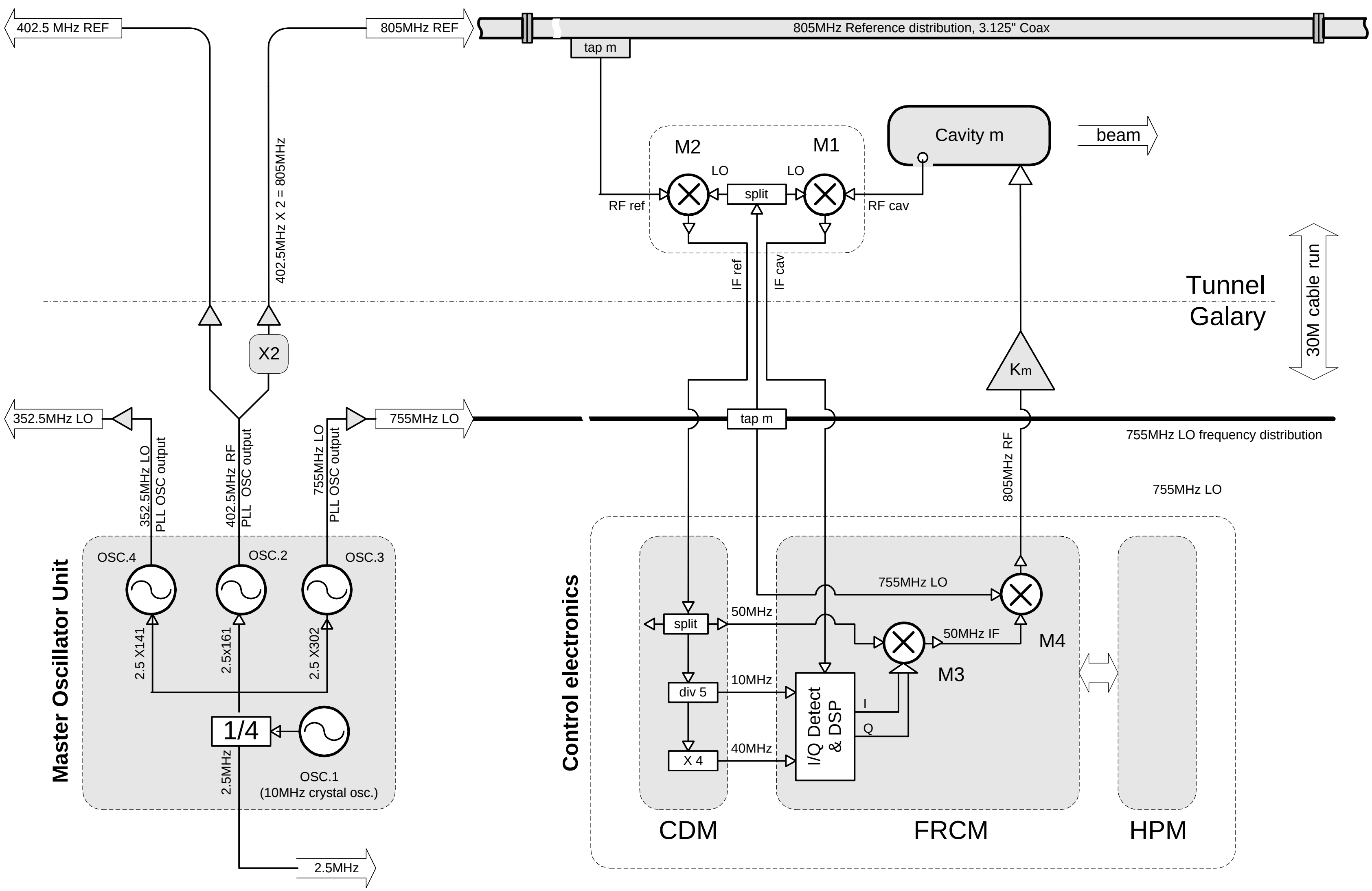
1-2. System Hardware Components - Master Oscilltor Unit

1. Synchronous oscillator outputs that are used: 402.5MHz RF, 755MHz LO, 352.5MHz LO
2. Synchronous oscillator outputs available ,but not used: 805MHz, 2.5MHz, 10MHz



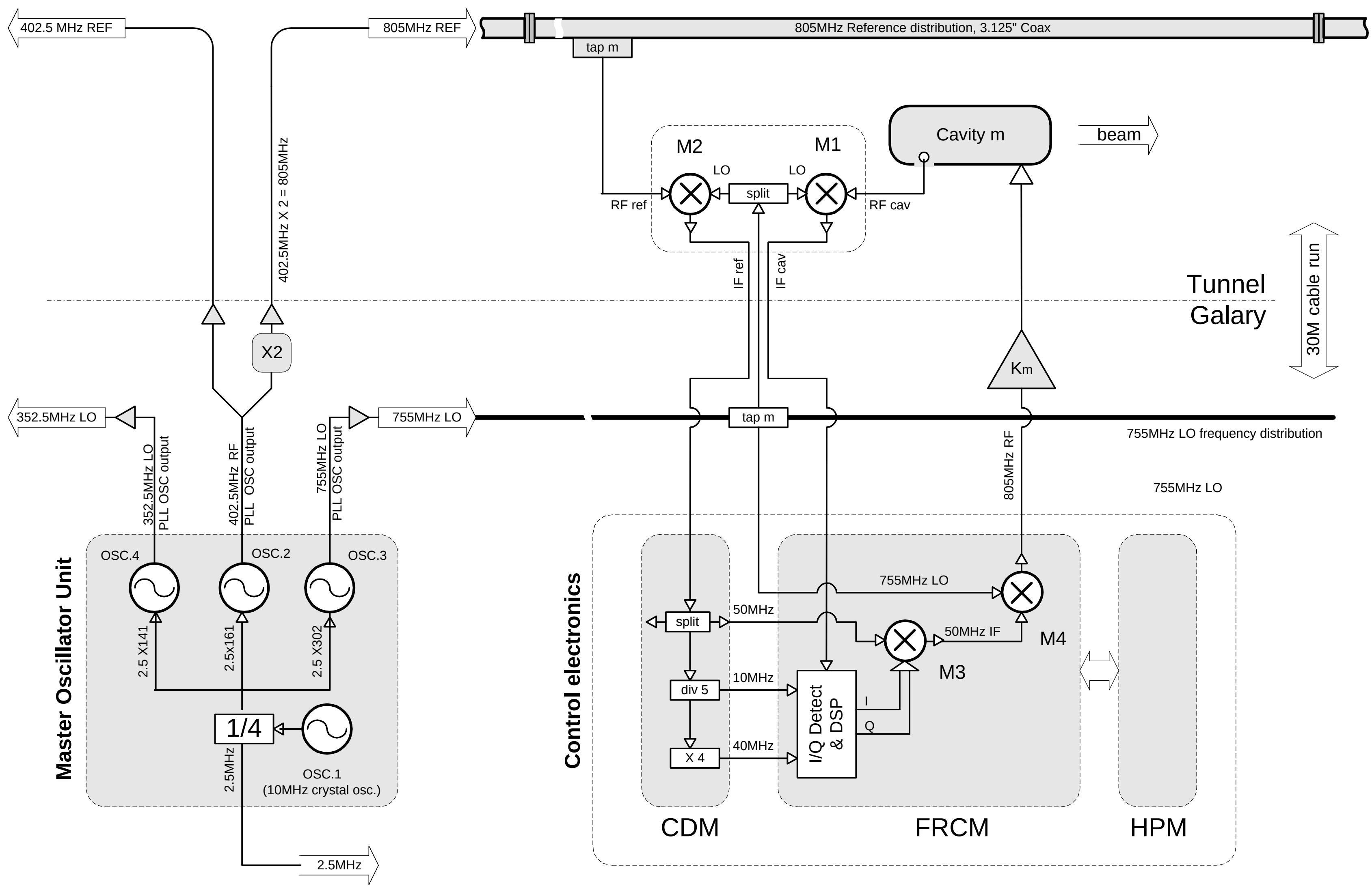
1-3. System Hardware Components - Control electronics

1. FRCM: regulates the phase and amplitude of cavity RF using feedback and feed forward, keeps the cavity resonant,
2. CDM: from 50MHz Ref input, generates 40MHz smapling clock and 10MHz sync. marker,
3. HPM: protects the system from over-power, spark etc.



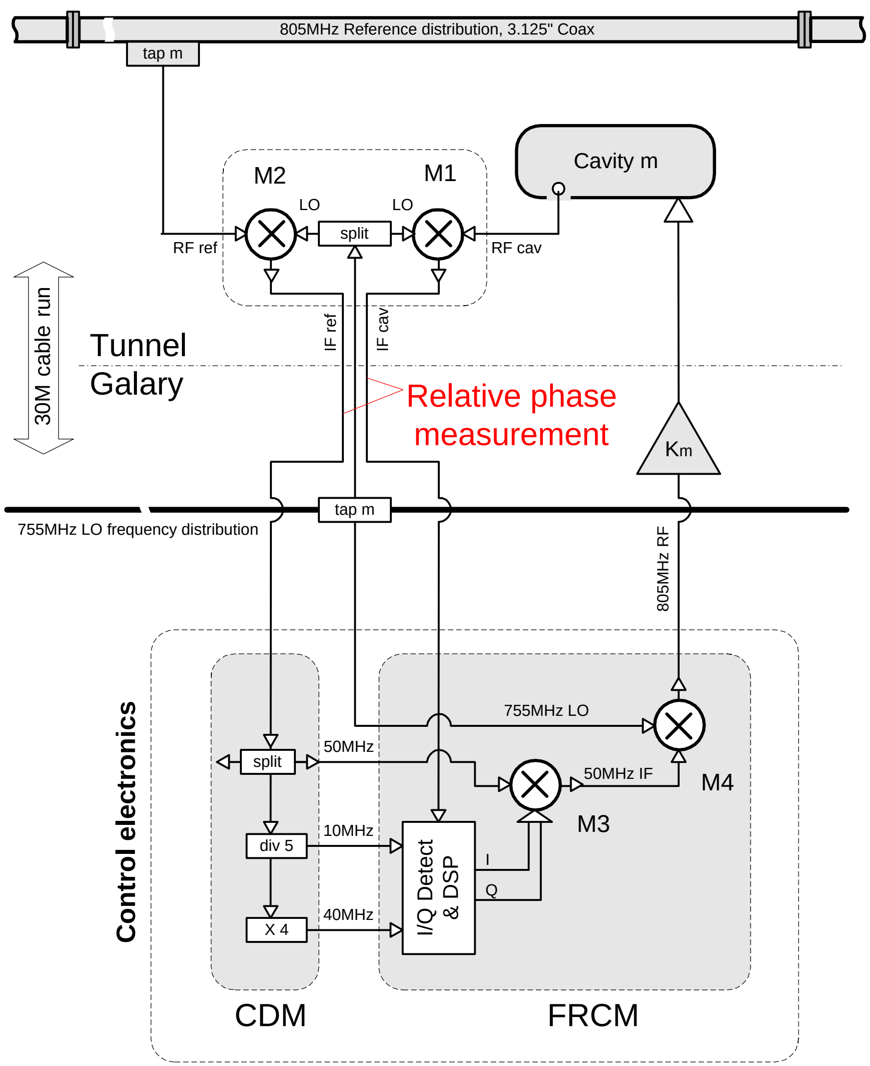
1-4. System Hardware Components - The point of this scheme

1. Obtains a total coherence between 402.5 and 805MHz reference, and uses a matched pair of feed lines for driving the ref. coax
2. Obtains a 40MHz sampling clock that follows the Reference and LO
3. Minimizes phase measurement error (due to temperature changes) by using a matched cable pair for IF_ref and IF_cav.



2-1. Phase/Amplitude Measurement of Cavity RF

1. Method of signal processing - Quadrature detection ("I&Q demodulation")



Given reference IF $IF\_ref(t) = COS(\omega_I t + +\phi + \delta)$

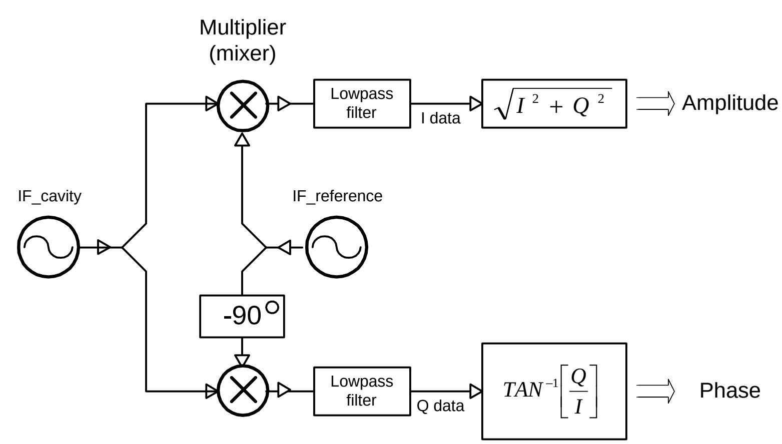
and cavity signal IF $IF\_cav(t) = A \times COS(\omega_I t + \varphi + \phi + \delta)$

where A and φ the amplitude and phase to be measured, while ϕ is static initial phase and δ is the common-mode phase error

then,

$$
\begin{aligned}
I &= IF\_ref(t) \times IF\_cav(t) \\
&= A \times COS(\omega_I t + \phi + \delta) \times COS(\omega_I t + \varphi + \phi + \delta) \\
&= \frac{A}{2} \times COS(\varphi) + \frac{A}{2} \times COS(2\omega_I t + \varphi + 2\phi + 2\delta) \\
&= \frac{A}{2} \times COS(\varphi)
\end{aligned}
$$

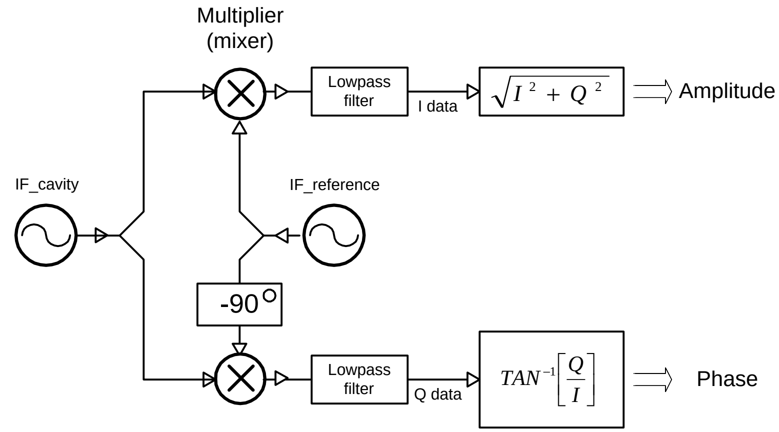
$$
\begin{aligned}
Q &= IF\_ref(t - T/2) \times IF\_cav(t) \\
&= A \times SIN(\omega_I t + \phi + \delta) \times COS(\omega_I t + \varphi + \phi + \delta) \\
&= \frac{A}{2} \times SIN(\varphi)
\end{aligned}
$$

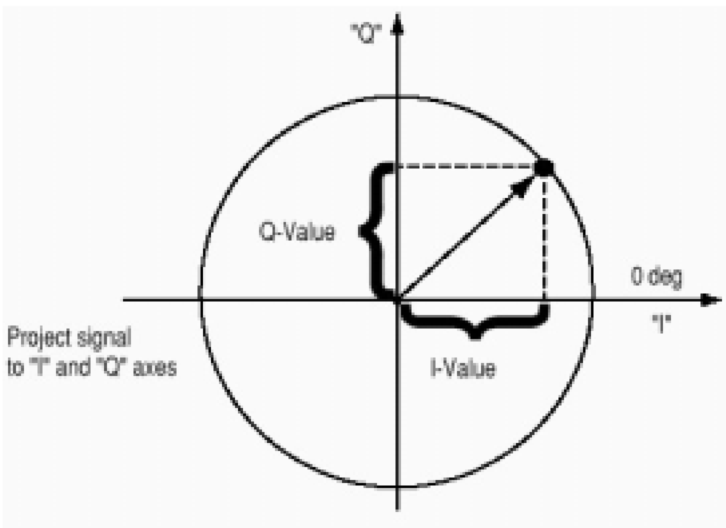


2-2. Phase/Amplitude Measurement of Cavity RF

1. Method of signal processing - Quadrature detection (continue)

Another way of looking at the problem is to consider the signal IF_cav under measurement in as a complex phasor in the 2-D coordinate of the reference IF_ref.





Polar to Rectangular Conversion

Given reference IF $IF\_ref(t) = COS(\omega_I t + +\phi + \delta)$

and cavity signal IF $IF\_cav(t) = A \times COS(\omega_I t + \varphi + \phi + \delta)$

where A and φ the amplitude and phase to be measured, while ϕ is static initial phase and δ is the common-mode phase error

then,

$$\begin{aligned} I &= IF\_ref(t) \times IF\_cav(t) \\ &= A \times COS(\omega_I t + \phi + \delta) \times COS(\omega_I t + \varphi + \phi + \delta) \\ &= \frac{A}{2} \times COS(\varphi) + \frac{A}{2} \times COS(2\omega_I t + \varphi + 2\phi + 2\delta) \\ &= \frac{A}{2} \times COS(\varphi) \end{aligned}$$

$$\begin{aligned} Q &= IF\_ref(t - T/2) \times IF\_cav(t) \\ &= A \times SIN(\omega_I t + \phi + \delta) \times COS(\omega_I t + \varphi + \phi + \delta) \\ &= \frac{A}{2} \times SIN(\varphi) \end{aligned}$$

2-3. Phase/Amplitude Measurement of Cavity RF

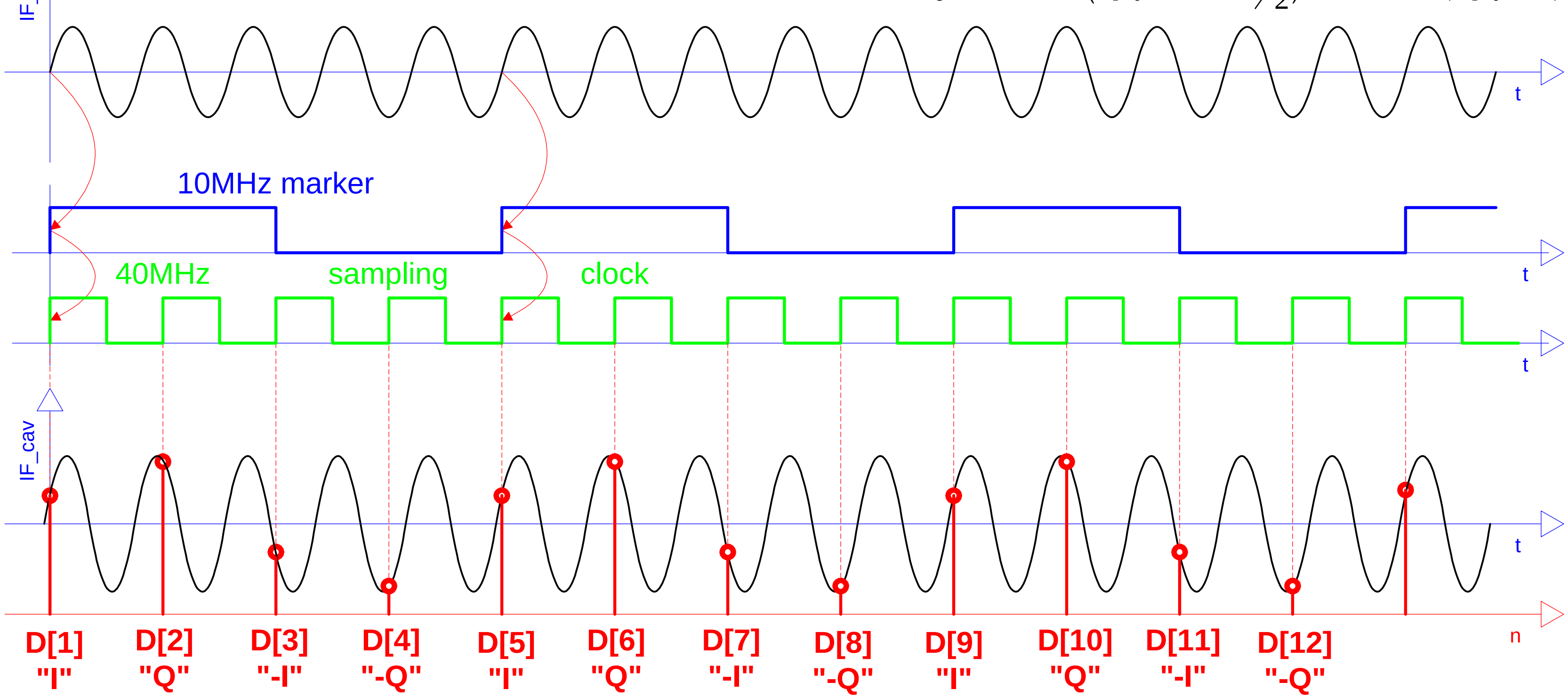
2. I-Q demodulation - doing it DSP style.

- Very slow changing phase and amplitude
- Sequential detection of I & Q data through sampling

$$10MHz\_marker = 50MHz\_IF\_ref \div 5$$

$$40MHz\_sampling\_clock = 10MHz\_marker \times 4$$

$$D_1 = A \times COS(\omega_I t_0 + \varphi) = I$$
$$D_2 = A \times COS\left(\omega_I t_0 + \varphi - {5\pi}/{2}\right) = A \times SIN(\omega_I t_0 + \varphi) = Q$$
$$D_3 = A \times COS\left(\omega_I t_0 + \varphi - {10\pi}/{2}\right) = -A \times COS(\omega_I t_0 + \varphi) = -I$$
$$D_4 = A \times COS\left(\omega_I t_0 + \varphi - {15\pi}/{2}\right) = -A \times SIN(\omega_I t_0 + \varphi) = -Q$$
$$D_5 = A \times COS\left(\omega_I t_0 + \varphi - {20\pi}/{2}\right) = A \times COS(\omega_I t_0 + \varphi) = I$$
$$D_6 = A \times COS\left(\omega_I t_0 + \varphi - {25\pi}/{2}\right) = A \times SIN(\omega_I t_0 + \varphi) = Q$$
$$D_7 = A \times COS\left(\omega_I t_0 + \varphi - {30\pi}/{2}\right) = -A \times COS(\omega_I t_0 + \varphi) = -I$$
$$D_8 = A \times COS\left(\omega_I t_0 + \varphi - {35\pi}/{2}\right) = -A \times SIN(\omega_I t_0 + \varphi) = -Q$$



2-4. Phase/Amplitude Measurement of Cavity RF

3. Digital Feedback Loop for RF Control

Again,
The key is group movement for reference and cavity RF signal under measurement.

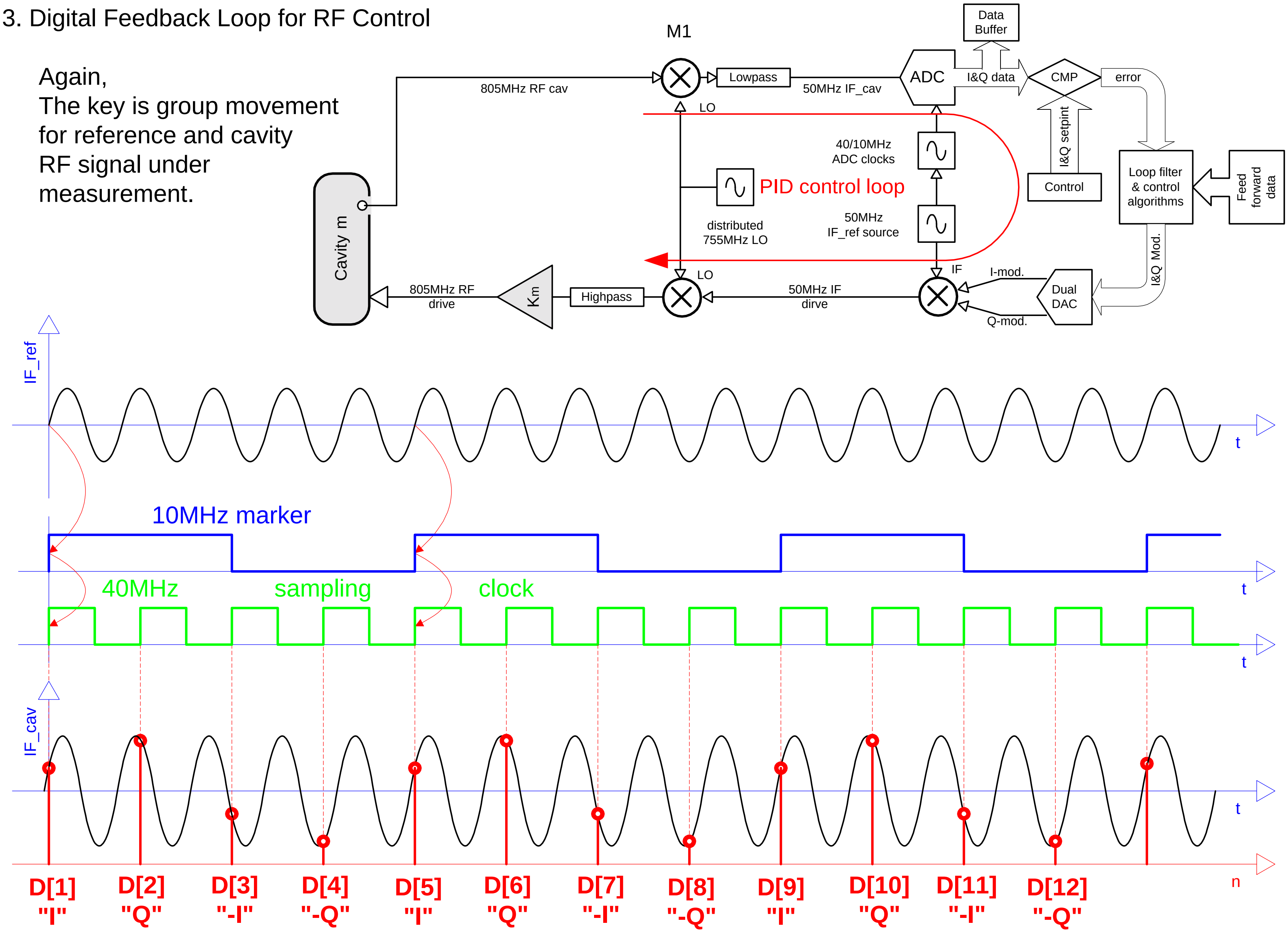


Fig. 2. RF Control System (one high-beta SRF "twin" section shown)

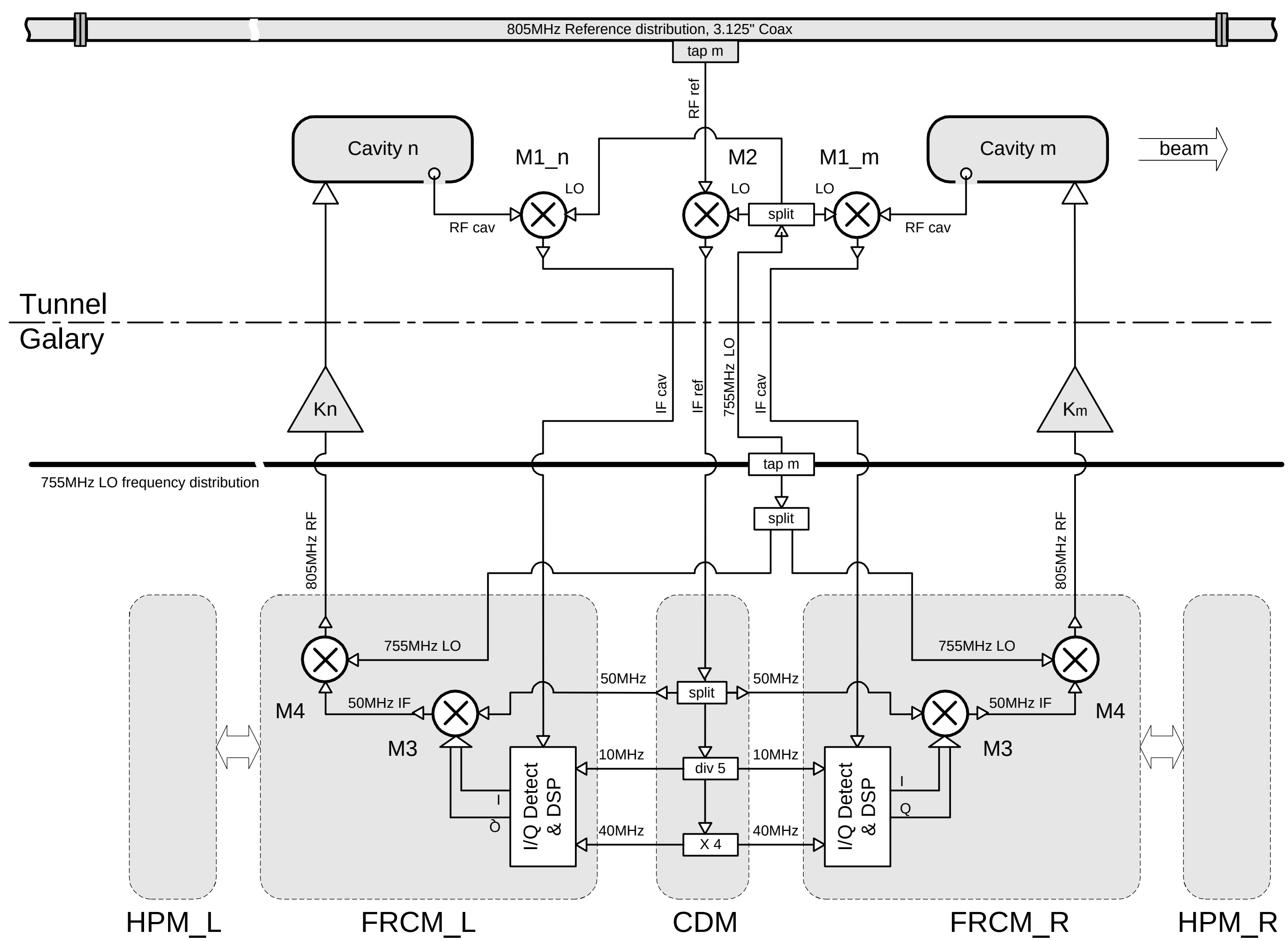


Fig. 3 Original Plan of RF Control System (one CCL section shown)